THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

INSIDE

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THE SECRETS OF COMBAT AIRCRAFT REVEALED

SCIENCE ENVIRON... OLOG... T... HISTORY SPACE

THE SINKING OF TITANIC
The science behind how the unsinkable ship went down

NEXT-GEN CAMERAS
Inside today's smartest and most powerful models

SEA ICE
How the Arctic Ocean becomes a frozen sheet

984 FACTS AND ANSWERS INSIDE

ASTEROID STRIKES / ICE AGES / HUMAN IMPACT

SURVIVING EXTINCTION

EXPLAINED: HOW ENTIRE SPECIES CAN BE WIPED OUT

SNEEZING
Can humans really sneeze at 100 miles per hour?

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Under the hood of these versatile military jeeps

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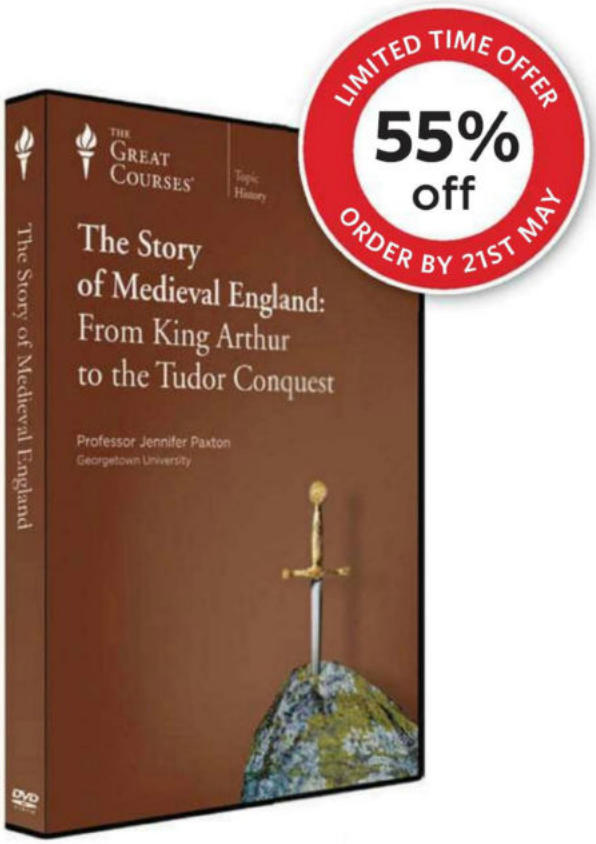

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23. The Conquests of Edward I
24. Edward II—Defeat and Deposition
25. Edward III and the Hundred Years' War
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27. The Black Death
28. The Peasants' Revolt of 1381
29. Chaucer and the Rise of English
30. The Deposition of Richard II
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HOW IT WORKS
ISSUE 32

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FEED YOUR MIND!

While life on Earth is both abundant and varied it is also precious and vulnerable. Every day, species are dying out. Many, like the critically endangered giant panda, have gained fame and relatively substantial support in the crusade to avert their extinction. Many thousands of other species, however, are simply fading quietly into obscurity as the challenges to their survival proceed seemingly unchecked. So the question is: should we care?

I hope that after reading our Extinction cover feature, you will. Within these pages you'll discover some frankly mind-blowing information about not only prehistoric creatures and the mass-extinction events of tens of millions of years ago, but also an eye-opening look at the scene today. Read on and you'll discover the scientific causes and reasons for a species to be wiped out, learn how animals can adapt to avoid extinction, and also find out about the species which are perching perilously on the IUCN's Red List – a kind of official 'species inventory' for planet Earth. Could we even bring mammoths back to life? Find out on page 12.

Also this issue we highlight the hundred-year anniversaries of both the sinking of the Titanic as well as the ill-fated journey to the South Pole made by Robert Falcon Scott and his intrepid team of explorers back in 1912. Well worth remembering. Enjoy the issue.

Helen Laidlaw
Editor

Meet the team...

Dave
Ed in Chief
Discovering the sheer feat of human endurance involved in the epic expedition to the South Pole made by Robert Falcon Scott and his team was both remarkable and humbling.

Robert
Senior Staff Writer
I spent a good chunk of this month penning our Extinction feature, which was both enlightening and shocking. The massive scale of human-caused extinctions must be addressed.

Jonny
Staff Writer
It's 100 years since the RMS Titanic sank, and this issue I leaped at the chance to rediscover the story and science behind this incredible passenger liner's untimely end.

Adam
Senior Sub Editor
I too was appalled by the growing ubiquity of extinction. On a trip to Japan last year, I saw many markets selling various animal parts, but our feature reveals it's a global crisis.

THE SECTIONS

The huge amount of info in each issue of **How It Works** is organised into these sections

ENVIRONMENT
The splendour of the natural world explained

TRANSPORT
Be it road, rail, air or sea, you'll find out about it in transport

HISTORY
Your questions about how things worked in the past answered

SCIENCE
Explaining the applications of science in the contemporary world around us

SPACE
From exploration of our solar system to deep-space adventures

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

WITH THANKS TO...

How It Works would like to thank the following organisations for their help

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CONTENTS

The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the experts in this issue's edition of How It Works...

Mike Anderiesz
Olympic physics

Techno-evangelist and author Mike writes on a wide range of science and tech subjects, from televoting to MMOs and beyond. This issue he explains the physics that will be on display at this year's Olympics.

James Baker
Humvees

Discover what's under the hood of the awesome military Humvee as tech-savvy James this issue reveals the amazing armour, firepower, manoeuvrability and versatility of this familiar multipurpose 4x4.

Shanna Freeman
Retinas

One of How It Works magazine's longest-serving – and favourite – experts, Shanna fills you in on the incredible anatomy inside your eyes by explaining the sight-giving abilities of the retina.

Lynsey Porter
Protein

Looking at the science behind how your body makes those essential protein compounds, this issue biology buff Lynsey has all the answers. Turn to page 59 for the lowdown on the process.

Nigel Watson
Scott of the Antarctic

Robert Falcon Scott was born in Devonport, very near to Plymouth, Nigel's hometown. Tasked with narrating this epic journey, Nigel paid a visit to Plymouth Library's exhibition on the intrepid explorer.

Alasdair Stuart
Fuel gauges

This issue, Alasdair turns his hand to a number of transport topics for your delectation, including how fuel gauges work as well as what goes on inside car headlights.

12 SPECIAL FEATURE

Surviving extinction

Learn everything you never knew you needed to know about the topic of extinction, a subject that goes back millions of years and yet still has massive implications today

ENVIRONMENT

24 **Sea ice**
Find out exactly what happens when the Arctic Ocean becomes so cold it turns into an ice sheet

26 Earthworms
26 Windchill factor
26 La Brea Tar Pits
27 World's biggest flower

30 **The giant anteater**
An odd-looking creature but one with highly specialised anatomy for surviving on little bugs alone

TECHNOLOGY

32 **Counterfeit money**
Discover the creative measures put in place to prevent crooks making cash forgeries

34 Classic jukeboxes
34 Waterjet cutters
36 Evolution of... printers
38 PlayStation Vita
40 Clothes dryers
40 Surround-sound headphones
41 Defibrillators

42 **Next-gen camera technology**
Inside the latest hardware and functions which are helping you to take better photos than ever

TRANSPORT

46 **Future fighter jets**
We take to the skies to bring you the lowdown on the most advanced multirole strike aircraft in the world

52 Fuel gauges
52 Headlights
53 RIB vessels

54 **Humvees**
Take a look at the abilities of one of the most hi-tech and versatile vehicles in the military today

SCIENCE

56 **Retinas**
How do the photoreceptive cells at the back of the eye create the pictures that we see?

59 Making protein
60 Pesticides
60 Centre of gravity
61 Sneezing

62 **Olympic physics**
The science behind your favourite Olympic sports events explained step by step

SPACE

64 **How does Earth spin?**
Don't get dizzy as you take in this article on planet rotation and how the Earth spins on its axis

67 Maxwell Montes
68 Hawking radiation
68 Telstar 1

70 **Cosmic expansion**
We know the universe is growing, but how, and when will it stop?

HISTORY

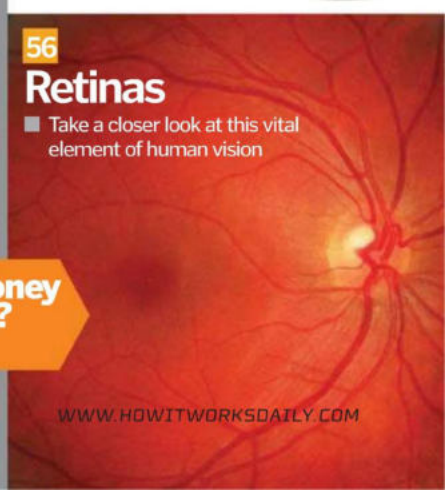
74 **Titanic**
On the 100th anniversary of the sinking of the most famous passenger ship in history, discover the science of how it sank

78 Hallmarks
79 Pompeii

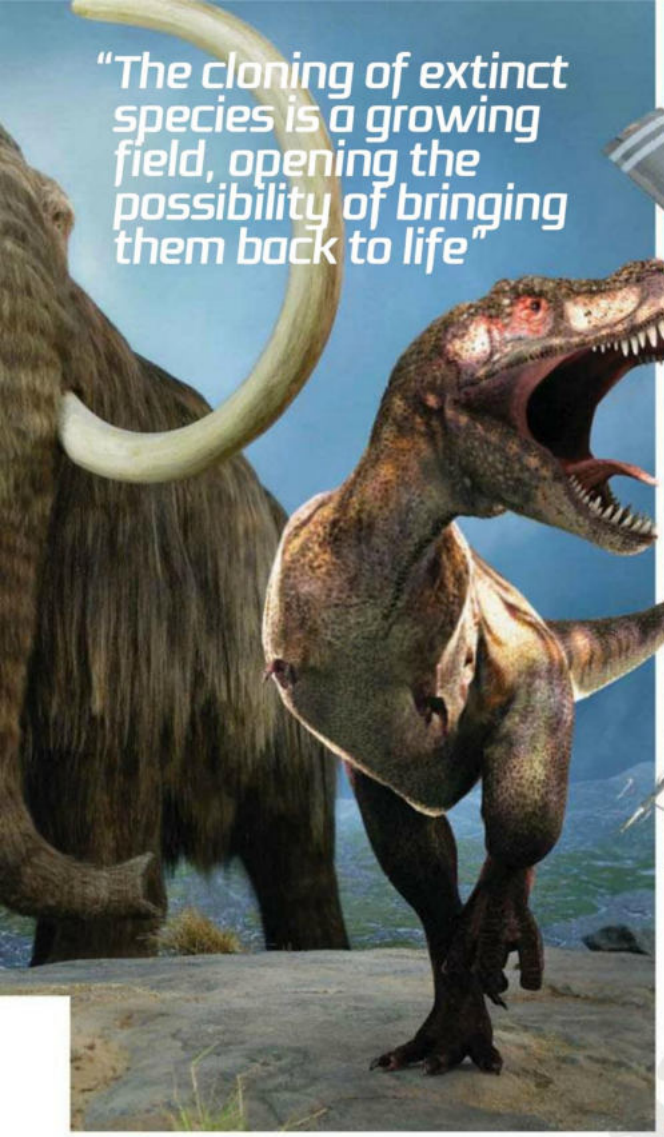
80 **Scott of the Antarctic**
Take a journey to the South Pole and learn of the intrepid yet ill-fated expedition that saw five men reach the Pole against all odds

30 The giant anteater
Learn all about these unusual animals native to Central and South America

56 Retinas
Take a closer look at this vital element of human vision



Ever wondered how money forgers are caught out?
Go to page 32 to find out!



46
Future jet fighters
Check out the high-flyers from the military aircraft scene

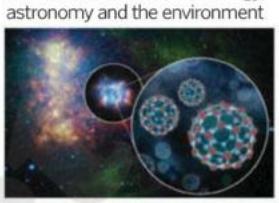
62 Olympic physics
With the Games on their way, brush up on the science behind the events

64 How Earth spins
For once and for all, find out what makes the world go round...

74
Titanic
A century since it hit that iceberg, do we know what happened and have we learned any lessons?

REGULARS

06
Global eye
Discover the latest news and read the greatest stories from the fields of science, technology, astronomy and the environment



82
Brain dump: Q&A with top experts
A host of the finest experts, curators and professors from museums worldwide answer your burning questions

88
The knowledge: gear and gadgets
Advice on the articles of desire you should be spending your money on in our latest reviews

90
Group test
For the most pimped-out phone ever, check out our smartphone accessories roundup

94
How to make...
...a do-it-yourself lava lamp

95
Test your knowledge
Put what you've learned this issue under scrutiny in our quiz

96
Letters
Get in touch and have your say on any subject. Get something off your chest or regale us with your scientific wonderings

GLOBAL EYE NEWS

Showcasing the incredible world we live in...

Mass
In their gaseous form, vast quantities of the balls have been discovered – a total mass of 15 times that of our moon, while in their physical form, enough have been found to fill 10,000 Mount Everests.

Location
The buckyballs were originally discovered by the Spitzer Space Telescope in the Small Magellanic Cloud, which is roughly 200,000 light years from Earth.

Extragalactic footballs represent building blocks of life

A unique football-shaped molecule has been discovered by the Spitzer Space Telescope, which scientists believe could be used for countless electrical and chemical applications

The Spitzer Space Telescope has discovered solid buckminsterfullerene molecules – nicknamed 'buckyballs' – for the first time. The exciting find comes a little less than two years after the unique microscopic carbon spheres were discovered for the first time in their gaseous form in the nearby Small Magellanic Cloud galaxy.

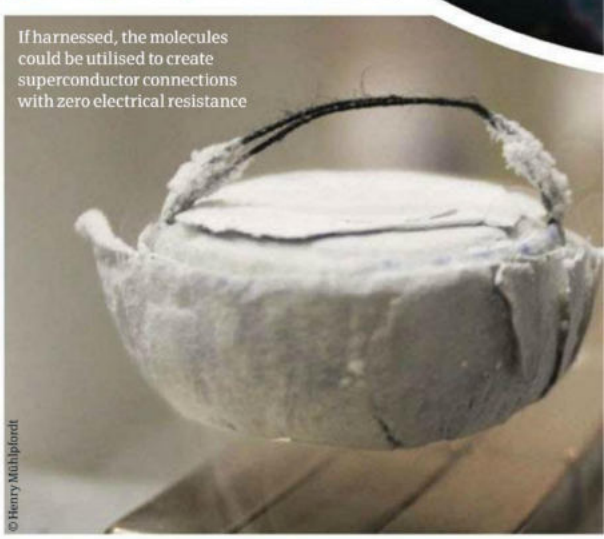
The buckyballs, which resemble the shape of a football, are made up of 60 carbon atoms arranged into a hollow sphere and, due to their unusual structure, are ideal candidates for electrical and chemical applications on Earth – ranging from the creation of superconductors to advanced medicines and super-efficient water purifiers to bulletproof armour.

The solid buckyballs were discovered when scientists detected tiny specks of matter, or particles, consisting of stacked groups of the material around a pair of stars called XX Ophiuchi, which are 6,500 light years from Earth. Interestingly, the buckyballs were found in vast quantities, with that detected enough to fill the equivalent in volume to 10,000 Mount Everests.

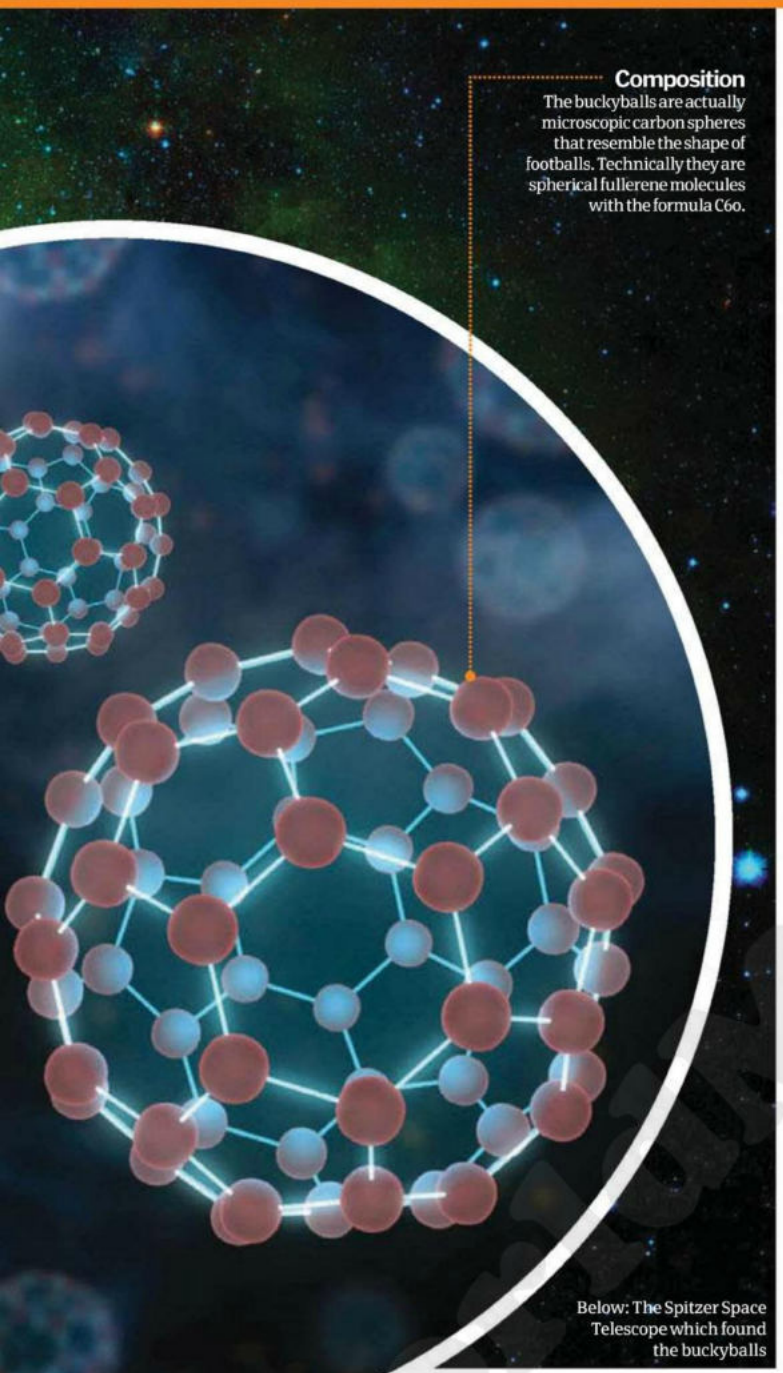
Speaking on the groundbreaking discovery, field expert Nye Evans of Keele University in England, said: "The particles we detected are minuscule – far smaller than the width of a hair – but each one would contain stacks of millions of buckyballs."

The revelation is seriously exciting the scientific community as the discovery of solid spheres seems to indicate that large quantities of these molecules must be present in stellar environments in order to link up and form solid particles. As such, they may be an all-important form of carbon and essential building block for life throughout the cosmos, though this still requires further research before it's confirmed.

Bill Danchi, the programme scientist of the Spitzer Space Telescope at NASA headquarters in Washington, commented: "The window Spitzer provides into the infrared universe has revealed beautiful structure on a cosmic scale. In yet another surprise discovery from the mission, we're lucky enough to see elegant structure at one of the smallest scales, teaching us about the internal architecture of existence."



If harnessed, the molecules could be utilised to create superconductor connections with zero electrical resistance

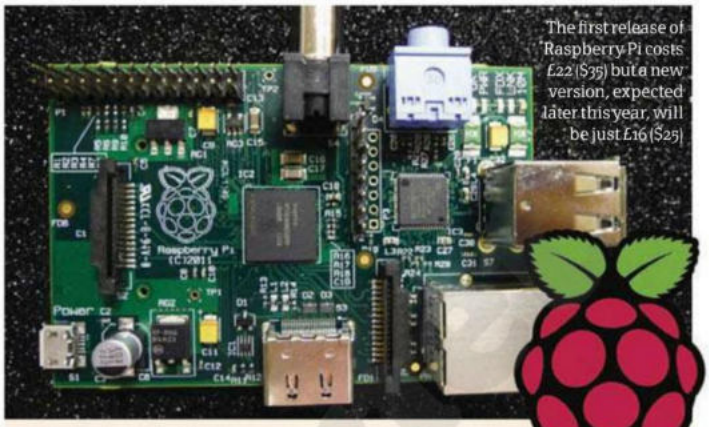


Below: The Spitzer Space Telescope which found the buckyballs

Buckminsterfullerene can be found on Earth in the minerals shungite and fulgurite

© Caehnaller Jochen

2x © NASA



The first release of Raspberry Pi costs £22 ($35) but a new version, expected later this year, will be just £16 ($25)

Raspberry Pi computer launched

A £22 computer on a tiny circuit board aims to improve programming know-how

A new bare-bones, open board computer called Raspberry Pi has been released with the aim of educating students in the workings of modern computer systems and how they are programmed.

The device, made by a Cambridge-based non-profit group, comes in two slightly varying forms. Both models come with an ARM single-core processor, a VideoCore IV GPU capable of HD video playback and an SD card slot for storage. However, the Raspberry Pi Model A board provides users with 256MB of RAM and a USB port, while Model B adds an extra USB port and a network-connectable Ethernet port.

Out of the box, users of the Pi need to only plug in a keyboard/mouse and install a Linux operating system for the device to be fully functional. This was ratified by demand for the device, with the first batch of 11,000 boards selling out within 24 hours.

Speaking on the intense demand for the Pi, Harriet Green, chief executive of Premier Farnell – the Pi's primary UK distributor, said: "I think a lot of teachers, parents and children are worrying that they're becoming just consumers – taking something out of a box and plugging it in. There's a lot of concern [over] children being just consumers rather than creators and innovators."

© British Science Association

Aberdeen to host British Science Festival

The British Science Association announces that its 2012 festival will be held in Scotland

The British Science Association has announced it will be making Aberdeen its home from 4-9 September 2012 for its annual British Science Festival. Offering five days where the streets of the city will be paved with all things 'science', the festival promises to deliver family entertainment, debates and the latest discoveries from the fields of science, technology and engineering. With this year's festival theme being Energising Minds, it promises to be the perfect opportunity for inquisitive and knowledge-hungry readers to feast on a wide array of factual goodness.

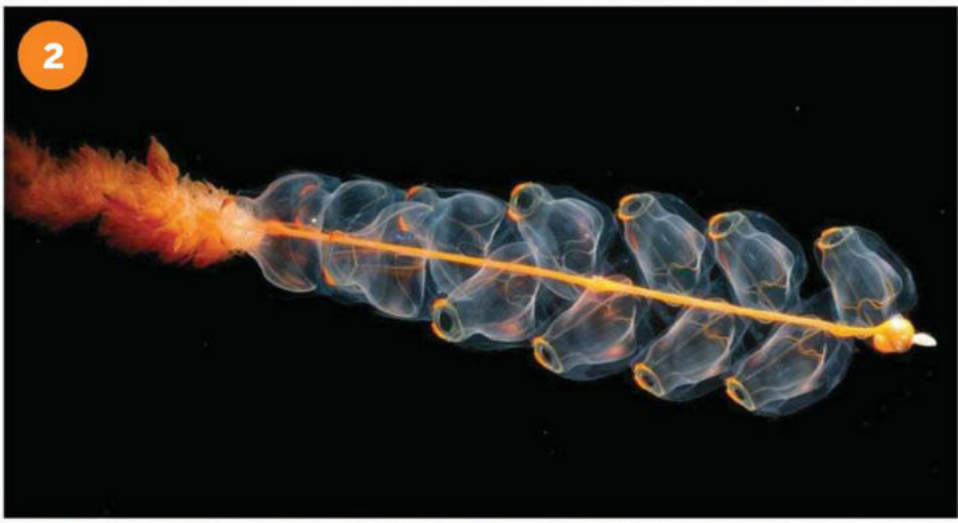
For more information about what's planned for this year's British Science Festival, pay a visit to **www.britishsciencefestival.org** or call 08456 807 207.

GLOBAL EYE NEWS

WHAT ON EARTH IS IT?

A close-up look at the world!

1



2

3

We reveal the true identity of the weird and wonderful images posted on HIW Daily, plus a few of your suggestions...

What is it?

1. Hopper

This is a stunning image of the species hemikypta marginata, a type of treehopper insect that is part of the membracidae family. There are roughly 3,200 known species of treehoppers in over 600 genera worldwide, with variants being found on every continent on Earth bar Antarctica. This species is most well known for its large and ornate pronotum (a part of the outer shell), which resembles a pair of horns.

Your best answers:

'Is it the head of a beetle?' **Matt Lathan** *'Scorpion?'* **Kevin Bragg**

What is it?

2. Siphon

This is a typical specimen of marrus orthocanna, a siphonophore species commonly found in Arctic seas. When fully grown, this unusual creature can reach several metres in length and its tentacles extend up to 50 centimetres (20 inches) on either side, allowing it to snare small crustaceans like krill. Anatomically, the siphonophore is actually composed of multiple zooids (independent bodies that live as one organism), which are linked together on a long stem.

Your best answers:

'I think it's a squid' **Ashwin Kumaar** *'Is it a jellyfish?'* **Tom Boon**

What is it?

3. Lion

Amazingly, this is a super-close-up shot of the head of a dandelion, with a few of its seeds removed. Dandelions are a member of the asteraceae family and produce seeds asexually. Dandelions can be found in countries all round the world and are largely considered beneficial weeds, drawing nutrients into their surrounding soil and frequently attracting pollinating insects to the local area.

Your best answers:

'It must be a weird pufferfish!' **Ashwin Kumaar**
'Is it the head of a dandelion?' **Chris Page**

To get involved, visit WWW.HOWITWORKSDAILY.COM to make your guess now!

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THIS DAY IN HISTORY

22 MARCH: How It Works issue 31 goes on sale, but what else

238 Gordian I and his son Gordian II are proclaimed Roman Emperors.

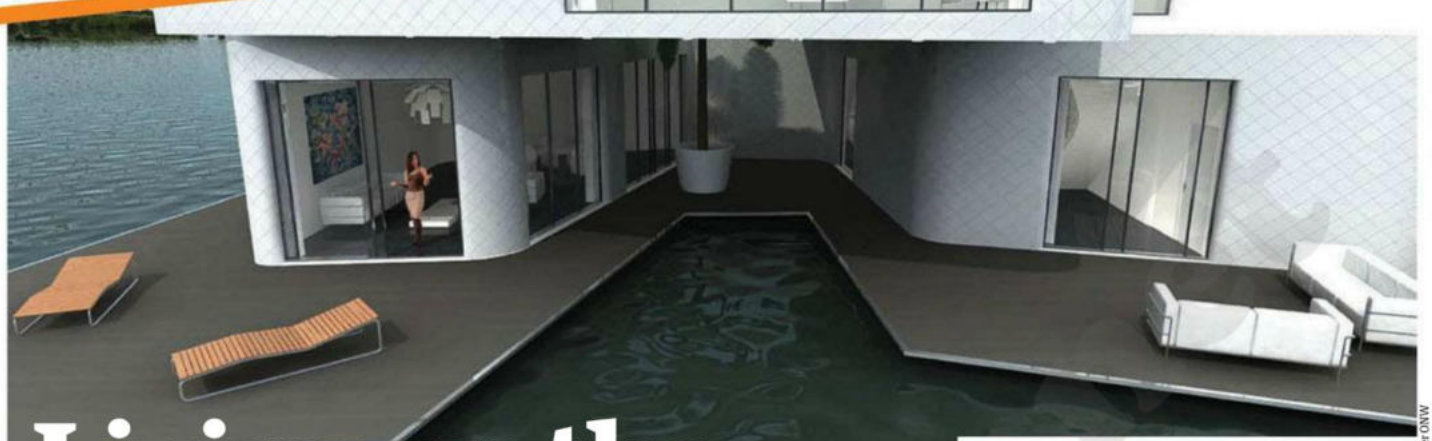
1630 The possession of cars, dice and gaming tables is outlawed in the Massachusetts Bay Colony.

1784 The Emerald Buddha is moved with great ceremony to its current location in Wat Phra Kaew, Thailand.

1873 The Spanish National Assembly in Puerto Rico approves a law to abolish slavery.

1888 The English Football League is founded, the oldest association football league in the world.

"This could be the most sustainable way to build in the future"



Living on the (water's) edge

This issue, technophile Pollyanna Woodward considers the technology behind the concept of constructing a modern-day floating city

©Anna Fowler

Venice (aka the floating city) is an intriguing place, where many a movie scene has been set, showcasing its uniqueness. I've wandered the streets and often stopped to look at the walls that plunge deep into the water and marvel at how the place still stands and exists. What's interesting today, however, is that floating buildings and cities are becoming a lot more popular. It was a conversation over dinner in Dubai that led me to think about this topic. We were talking about 'The World', the artificial archipelago constructed off the coast of Dubai – manmade islands arranged in the shape of the world map. But what about the towns, cities and countries around the globe that are situated so dangerously low that they are actually at risk of disappearing below sea level, like the Netherlands?

There are numerous projects looking to build 'amphibious houses' constructed on floating platforms. While this technology has actually been around for some time, it's now becoming increasingly advanced and genuinely sustainable. There are several big projects in the pipeline as well as discussions about building an entire apartment block on the water. The pioneer behind these concepts and designs is Dutch architect Koen Olthuis, who also wants to build roads and parks and create the whole infrastructure of a floating city. He believes this could be the most sustainable way to build in the future; when the life span of the building is up after 50 years the building is simply towed away and disposed of. So how do you maintain the floating platform below the construction? Surely it would need some kind of renewal or treatment by that point, but compared with knocking a structure down and removing the debris and so on, it's likely to be a lot more environmentally friendly.

The underwater floating structures used in the past have been relatively simple: layer upon layer of light plastic foam is used to hold and uplift the weight of the concrete. As you can imagine, this puts limitations on the size and weight of the structure of the building.

A joint venture between a Dutch company and a Spanish one is developing a new technology to float buildings that are more substantial in size and weight. That technology employs expanded polystyrene – the material we often use to protect fragile packages. The project will involve mixing the polystyrene blocks with concrete in different sections like building blocks, to create a floating platform that can endure over long periods and support great weights, making floating houses a realistic possibility. The creator of these ideas – Olthuis – has also designed a floating mosque for the UAE, an entire floating community for the Maldives, and he uses 3D modelling apps to help clients visualise how building on the water could change the world. I imagine that with such construction techniques still in their infancy it'll be some time before we see working, habitable floating cities.

An architectural visualisation of what could be the home of the future

2x © Architect Koen Olthuis, Waterstudio.NL and developer ONW

A shot of The World, a manmade group of islands off the coast of Dubai

© Nakheel PJSC

happened on this day in history?

1916 The last Emperor of China, Yuan Shikai, abdicates the throne.

1960 Inventors Arthur Schawlow and Charles Townes receive the first ever patent for a laser.

1982 NASA's Space Shuttle Columbia launches from the Kennedy Space Center.

1995 Cosmonaut Valeri Polyakov returns to Earth after a record 438 days in space.

2009 Mount Redoubt, an Alaskan volcano, begins erupting after a long period of inactivity.

10 AMAZING THINGS TO KNOW

THIS MONTH WE LEARNED...

1 41MP smartphone camera unveiled

Nokia has announced its new 808 PureView phone that should be with us by June 2012. The specs of the single-core mobile are pretty average save for one thing: its monster camera. This boasts a sensor resolution of 41 megapixels when shooting stills, which compares to just eight megapixels in most smartphones today. It uses a host of built-in tech to create amazingly true-to-life images.

2 Asteroid could hit Earth in 2040

A large asteroid known as 2011 AG5 could potentially strike Earth on 5 February 2040, experts say. The space rock is about 140 metres (460 feet) wide and would pose a serious threat to our world if it does collide. At the moment it's estimated to have a 1 in 635 chance of hitting our planet, which sounds small but represents a significant probability. Further studies of the asteroid are needed and we probably won't know if it's a real risk until 2023 but, if it is deemed to be, then a multinational mission would have to be conducted to deflect it.

3 Google working on futuristic specs

By the end of the year Google plans to release a pair of ultra-high-tech glasses. These apparently will act like a mobile phone, with motion-sensing technology, GPS and even the ability to record video and take pictures. The augmented reality lenses will also let you view texts and emails, however Google doesn't have any plans to mass-produce the specs as yet.

4 Immortality may be a possibility

Scientists have found a species of asexual flatworm that can regenerate a part of its DNA (the telomere) that essentially allows them to live forever. The study, published in the *Proceedings Of The National Academy Of Sciences*, observed a group of these planarian worms and found they could continually grow new muscles, skin and even their own brain, providing key information that may eventually improve the longevity of human life.

5 Preserved ancient forest unearthed

A nearly 300-million-year-old rainforest has been uncovered in the province of Wuda in China. Dubbed the 'Pompeii of the Permian period', the remarkable forest was covered in volcanic ash an estimated 298 million years ago and has remained untouched until now. The archaeological site was unearthed in Inner Mongolia, China, during mining activities searching for coal. It's thought the 929-square-metre (10,000-square-foot) area was covered in ash in just a few days. Some of the specimens, including 24-metre (80-foot)-tall trees, were found in near-pristine condition.

6 Test-tube burger is coming right up

As reported back in issue 29 of **How It Works**, the world's first artificially created hamburger is expected to be produced later this year. The burger will be made from cow stem cells and has a 'release date' of autumn 2012, though with a price tag of €250,000 it's unlikely to be the new Big Mac just yet! The ingredients are still in the laboratory phase, but within six months the team from Maastricht University in the Netherlands expects to have thousands of small tissues that can be assembled into the finished product.

7 Giant space water reservoir found

A huge expanse of water has been found orbiting a black hole. 12 billion light years away in a quasar known as APM 08279+5255, scientists have discovered the equivalent to 140 trillion times all the water on Earth. This quasar is from 1.7 billion years after the Big Bang, but is unlike anything observed before. The water is distributed as a vapour around the black hole in a gaseous region hundreds of light years in size.

8 Games to be controlled by eyes

A project at De Montfort University, UK, is aiming to make a revolutionary method of input so that severely disabled children can enjoy computer games. Their new input method is eye control, which tracks the motion of a person's eyes to enable them to interact with devices with their sight alone as they might be unable to use a mouse, keyboard or other peripheral. Looking at different points on screen will 'push' virtual buttons to move and interact with in-game characters.

9 Japan to construct a space elevator

Japanese construction company Obayashi Corporation has said it plans to build a space elevator that can take passengers 36,000 kilometres (22,350 miles) above Earth by 2050. The lift will be made of carbon nanotubes attached to a counterweight 96,000 kilometres (60,000 miles) above our planet, one-quarter of the distance to the moon. Cars on the elevator will each transport 30 passengers at a speed of 200 kilometres (124 miles) per hour, reaching their destination in about a week.

10 Ponytails are maths marvels

The measure of how the curliness of hair affects ponytails has remained a mystery for 500 years. However, scientists from Cambridge and Warwick universities say they have devised a Ponytail Shape Equation, which uses a ratio between the effects of gravity and the length of hair (the Rapunzel number) to accurately calculate the shape of a ponytail. The research could help us better understand the structure of materials made of natural fibres like wool and fur.

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SURVIVIN
EXTIN

G CTION

From cosmic collisions and severe changes in climate to poaching and habitat destruction, extinction is driven by many factors that only the most resourceful species can survive...

Often perceived today as a detached, artificial and random threat, trapped in deep geological time or areas of the Earth that we have little contact or relationship with, extinction is in fact an ever-present force that looms over all life. It is a reality of existence and an inevitable by-product of natural selection; if species survive by adaptation, then those that don't or can't die off. Natural organisms, born from our planet's natural environment, can also succumb to it – from environmental factors such as inter-species competition, volcanic activity and population saturation, through to atmospheric ones such as climate change, extinction is caused in a wide variety of ways. These causes form a lethal cocktail that, since life began on Earth, has claimed 99.9 per cent of all species to have ever existed.

Considering that humans are not only a biological species but merely one out of the countless millions to ever have lived upon this planet, it could be suggested that our relationship with extinction is not as separate as we might think. What makes our species impervious to extinction's causes? For instance, the Armageddon event at the Cretaceous-Tertiary boundary that wiped out the dinosaurs 65.5 million years ago would swiftly despatch us if it occurred today. The infectious pathogen that wiped out the native rats of Australia's Christmas Island resonates fiercely in a world of mutant strains of H5N1. While the ever-dwindling environments that helped claim many species, like mammoths, up to 10,000 years ago really hits home in a world where in each subsequent year an extra 134 million people are born.

But despite the many ways that we are subject to it, humanity is also now an active contributor to worldwide extinction. Today, while natural extinction remains as potent as ever, it has been bolstered by a raft of human-generated activities. Everything from deforestation to agricultural clearance, logging, habitat fragmentation, urbanisation, hunting, poaching, industrialisation, human-generated climate change and the black-market pet trade all play their part in wiping out species around the world, little by little, day in day out, rapidly increasing extinction rates to unprecedented levels.

And here lies the crux of the matter. The difference between homo sapiens' relation to extinction and that of any other species is conscience – the ability to make informed and reasoned choices. Many natural causes of extinction are beyond the control of any species – there is such a thing as bad luck – however many that blight some of Earth's most endangered animals can be prevented by humans. The key is choosing to do so. Luckily, today more people, institutions and projects than ever before are helping to maintain Earth's rich biodiversity by protecting the most-threatened fauna and flora. From non-governmental groups such as the World Wide Fund for Nature (WWF) and International Union for Conservation of Nature (IUCN), through to governmental and intergovernmental ones such as the United Nations Environment Programme (UNEP), the protection of the planet's environment and its wildlife is being taken more and more seriously.

In the following feature, **How It Works** explores extinction throughout Earth's history up to the present day, analysing its causes and effects, as well as how we today can play a small but arguably significant role in combating it.

Mass-extinction

Mass-extinction is characterised by a sharp and widespread decrease in the diversity of life, occurring when the rate of extinction increases beyond that of the rate of speciation (the creation of new species). In the past 540 million years, there have been five mass-extinction events, each claiming more than 50 per cent of animal species. The most recent of these was the Cretaceous-Tertiary (K-T) extinction event that wiped out all non-avian dinosaurs 65.5 million years ago; for a detailed analysis of this event, see the 'Mass-extinction breakdown' illustration on this page.

The K-T event resonates today for two reasons. Firstly due to the spectacular primary cause – a bolide (or super-large meteorite) impact with Earth – and secondly due to its extermination of the dinosaurs, an event that would eventually lead to the proliferation and evolution of

Sumatran rhino 220 left in wild today!

MASS-EXTINCTION STEP BY STEP

Follow How It Works' step-by-step guide to the catastrophic consequences of a meteorite impacting the Earth 65.5 million years ago

3. Carbon

The impact would have also generated a shock production of carbon dioxide and sulphur from the widespread destruction of carbonate rocks and direct collision with areas of ocean. This would have initiated a sudden greenhouse effect, heating the immediate environment and atmosphere. Oxygen levels were also greatly affected.

1. Armageddon

Judging by the remaining Chicxulub crater in the Yucatán Peninsula – dated to the K-T extinction event – the impacting object had an estimated diameter of 10km (6mi). This would have meant the resultant collision would have generated an explosion equivalent to the sudden detonation of about 96 teratons of TNT. To put this in perspective, the most powerful manmade explosive device ever detonated had a yield of 50 megatons of TNT (and there are 1 million megatons in a teraton). Compounding this impact was increased volcanic activity in the Deccan Traps of modern-day India.

4. Acid attack

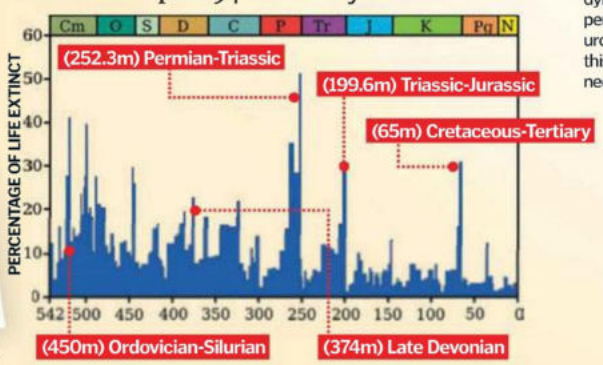
The sudden and large-scale release of huge quantities of carbon and sulphur dioxide would have then led to planet-wide acid rain. The rain would be increased due to the injection of water vapour – from the ocean collision – into the atmosphere.

5. Dead sea

Oceans worldwide – specifically those in close proximity to the impact – suffered massively, with thousands upon thousands of species, ranging from micro-biota through marine invertebrates and up to large species such as pliosaurs, dying off rapidly. For example, it has been calculated that 35 per cent of all Earth's echinoderms (eg starfish and sea urchins) became extinct at the K-T boundary. A key cause of this was the reduction of deep-sea currents, which are needed to oxygenate the ocean depths.

THE BIG FIVE BY NUMBERS

There have been five major mass-extinction events in the past 542 million years



6. Chain collapse

On land, the combination of the impact as well as the resulting catastrophic environmental and atmospheric changes initiated a food chain collapse. At the base, Earth's flora (particularly that which relied on photosynthesis) began to die off in large quantities due to the lack of sunlight and extreme weather. This led to a major reshuffle in dominant plant groups.

2. Paradise lost

The impacting explosion was then followed by a lethal cocktail of megatsunamis – estimated to have reached thousands of metres high, super-heated dust clouds and widespread volcanic activity. Further, ejected material alongside pieces of the impactor blown out of the atmosphere would have re-entered as superhot rock, scorching the Earth's surface and causing mass wildfires. The generated dust clouds would have covered the entire surface of the Earth, remaining in the atmosphere for up to a decade and severely blocking out the Sun.

7. Cold blood

With huge swathes of Earth's plants disappearing, insects and insect-eating reptiles/amphibians also began to die off due to scarcity of food sources. Importantly, organisms that fed off detritus generally survived, leading to an explosion of fungi and carrion-eating insects. The avian dinosaurs that had not been killed off due to atmospheric changes also now began to decline for the same reasons, as most were pure carnivores. Small species of early birds survived thanks to the many worms and snails around.

8. Beginning of the end

The collapse of many of Earth's plant, insect and reptilian species then initiated the total extinction of ground-based dinosaurs. Small dinosaurs such as pachycephalosaurus were wiped out quickly from malnutrition due to a lack of viable food sources.

10. King killer

With almost their entire food source being systematically eradicated, the largest – and usually most carnivorous – of the dinosaurs began to die out. Despite the tyrannosaurus rex's supreme physical power and dominance over other species, the combination of a lack of food, desolated environment and toxic atmosphere, rendered it powerless to avoid its fate.

11. Disaster taxa

Following this great cleansing of many of Earth's species, an intermediate period of growth and rebuilding began – one in which disaster taxa flourished. Disaster taxa are organisms that through their simple and rapid reproduction mechanism, as well as loose and flexible diet, manage to survive and multiply in large numbers.

12. Renaissance

After millions of years of regeneration, stable ecosystems began to emerge once more, driven by processes such as natural selection. These systems provided a base on which surviving clades (groups of organisms evolved from the same species) from the Cretaceous could flourish. New species developed too and many modern-day birds, reptiles, mammals and amphibians are descendents of this period.

9. Domino effect

As smaller dinosaurs began to die out, so did their larger brethren. It was not just medium-sized carnivores who suffered though – herbivores such as hadrosaurids also went into steep decline, as vegetation became scarce. Studies of Late Cretaceous hadrosaurs show that they started to eat decomposed wood material to try and gain some nutrients.

Interview Professor Mike Benton

HIW speaks to the professor of Vertebrate Palaeontology at the University of Bristol, UK

How It Works: How many mass-extinction events have there been since the planet formed?
Mike Benton: It's now thought five mass-extinctions have occurred in the past 500 million years – commonly referred to as the 'big five'. There were almost definitely other mass-extinction events before that in the pre-Cambrian but the knowledge of dating and quality of the information becomes very poor as you go deeper into time. So the big five people talk about are Late-Ordovician, Late-Devonian, Permian-Triassic, Triassic-Jurassic and Cretaceous-Tertiary. Of course, the one people have talked most about is the last one, which is when the dinosaurs went extinct.

HIW: The largest of these mass-extinction events was the Permian-Triassic. Can you tell us a little about it?
MB: Out of the big five the end-Permian is the biggest of all. So while the other four extinctions seemed to show a loss of around 50 per cent of species, which is a huge hit, the one at the end of the Permian is even more grim, as it delivered a loss of 80-90 per cent of species. It is on a very different scale; in fact, only one in ten of all the species survived through it. We are fairly confident that those figures and the distribution of that 80-90 per cent is fairly equal across marine and terrestrial, and across small and large creatures. It was quite non-selective – it was equally devastating for plants and animals.

HIW: What sort of timeframes are we talking about for an average mass-extinction event?
MB: I think we need to devise three phases. So, taking the K-T event as an example, the first phase probably just lasted for a couple of days and that was the instant effect of the impact. So the impact happens, a lot of local debris is dumped over the Mexican and Caribbean areas. However, the killing process is what follows. There is a tsunami that would have had a big effect in the surrounding vicinity but not worldwide. Then the worldwide effect, which happened over a couple of days, is the iridium-rich dust that was sent high into the atmosphere and then flushed out with rainfall all over the world. So it's a combination of a pulse of hot air that went all the way round the world, and then the dust. The dust blacked out the Sun – preventing photosynthesis – and created freezing conditions.

The second phase is after most of the dust has cleared, maybe a few weeks later, where there's a sort of silent time where all the dinosaurs are lying round dead, the world is half empty and ecosystems are imbalanced. Here, there is sort of instant recovery time, which may have lasted between 10,000-100,000 years. There is a quick recovery of certain species that can take advantage of these conditions; these are so-called 'disaster taxa', which quickly populate the Earth but are not long-lasting. Life is reconstructed, ecosystems are reconstructed but in a kind of mimic of reality that's not going to last long. So there is this disaster phase that was probably between 100,000-500,000 years. At this point, all sorts of lizards, crocodiles and birds popped up and started evolving as quickly as they could to take advantage of the areas that used to be dominated by now-extinct species.

Lastly, ecosystems start to stabilise and the longer-term third phase is what took 3-4 million years. At the end of that time you would have what we perceive as a stable ecosystem. These animals are the forerunners of most of the species that we see today.

DID YOU KNOW?
K-T boundary mammalian species were generally small, rat-sized creatures.

OUTRUNNING EXTINCTION

During the run-up to the end of the last ice age, many species tried to adapt to the ever-changing climate, migrating thousands of miles in an attempt to escape extinction

Megatherium

This elephant-sized ground sloth was endemic to South America and evolved there in isolation while it was still an island in the Paleogene epoch. As with the smilodon though, it migrated northwards into Central and North America in the Great American Interchange. Towards the close of the Pleistocene epoch, however, it is suggested that the rate of migration increased in partnership with the expansion of human hunters, who targeted the animal for its meat and fur. Its huge size – when standing on its hind legs it was six metres (20 feet) tall, omnivorous diet and large claws did help it to survive longer than other species of megafauna though.

Smilodon

Evidence suggests that each species of sabre-toothed tiger migrated over large distances in the period leading up to the end of the last ice age. Smilodon fatalis, which initially lived in North America, invaded western South America as part of the Great American Interchange – a mass-migration of many species across the Americas. However, as the glacial ice sheets retreated, many North American members of fatalis, as well as smilodon gracilis, would have migrated north to avoid the hotter, drier summers.

mammals across the planet. Interestingly, though, our perception of this mass-extinction is generally skewed today, with too great an emphasis placed on the bolide impact itself and less on the resultant and far more deadly series of knock-on effects, as well as a number of other contributing factors.

The Chicxulub crater, found today on the tip of the Yucatán Peninsula in Mexico, is widely considered by palaeontologists the area of impact for the K-T extinction bolide. The crater today measures 177 kilometres (110 miles) in diameter, a number that indicates the impacting meteorite was at least ten kilometres (six miles) in diameter when it struck Earth. While an impact of this magnitude obviously led to the immediate annihilation of many species, it would only do so in a relatively small area on a worldwide scale. The reasons that its effects were felt all the way around the planet was its generation of vast quantities of dust and toxic gases in the atmosphere. The dust, spread by Earth's winds, blocked out the Sun, resulting in the mass death of photosynthesising plants, while the toxic gases (eg carbon dioxide and sulphur oxide) generated vast quantities of acid rain. Combined, these two effects wiped out a huge proportion of the world's flora and, as a direct consequence, initiated a food chain collapse that extended all the way from tiny insects right up to large dinosaurs such as the tyrannosaurus rex. In addition, modern thinking suggests that during the time of the impact, the Deccan Traps of modern-day India were erupting, also causing significant climate changes.

> "Species such as the woolly mammoth, sabre-toothed cat, giant ground sloth and Irish elk all suffered due to habitat loss"

The K-T event, however, despite claiming 85 per cent of all species on Earth, is not the largest to have occurred throughout our planet's history. The Permian-Triassic (P-T) mass-extinction, which occurred 252.3 million years ago – and has been nicknamed both the 'Great Dying' and 'mother of all mass-extinctions' – claimed 96 per cent of all marine species, 70 per cent of all terrestrial vertebrate species, 57 per cent of all families and 83 per cent of all genera. (For more information on the P-T mass-extinction, check out the interview with expert in the field, Professor Mike Benton, on the previous page.)

Geo-climate extinction

Moving forwards in time, another cause of species extinction can be seen in the geo-climate changes of Earth's most recent ice age. This is but the last of what's believed to be a series of five major ice ages which have occurred since our world formed. Ice ages are characterised as a period of long-term temperature reduction and growth of continental and polar ice sheets, as well as alpine glaciers. Within an ice age there are both glacial (the last one peaked approximately 20,000 years ago) and interglacial periods, with the last glacial period ending approximately 10,000 years ago.

The run-up to and crossing of this boundary threw many notable species into decline. Creatures such as the woolly mammoth, sabre-toothed cat (smilodon), giant ground sloth and Irish elk all suffered due to habitat loss and vegetation changes. This global warming further caused the Earth's average sea level to rise and increase in temperature. This shift altered ocean currents and, as a direct consequence, affected the efficiency in which deeper areas were oxygenated and therefore the survival chances of a vast number of marine species.

Of course, interglacial periods can both aid and hamper speciation, with new species emerging thanks to favourable alterations to the environment and the decline of other competitor or predatory species. Further, it is easily argued that these types of extinction are both natural and beyond the control of Earth's

Extinction timeline

Many different species have become extinct over the past 250 million years. How It Works takes a look at some of the most notable...

250m

Blastoid

A prolific type of stemmed echinoderm, blastoids (sea buds) survived from the Ordovician to the Permian period, which ended 250 million years ago in the massive P-T mass-extinction event.

© Philip72

Recent evidence suggests woolly rhinos migrated from Asia to northern Europe in an attempt to avoid extinction

© Kirinko

Woolly rhinoceros

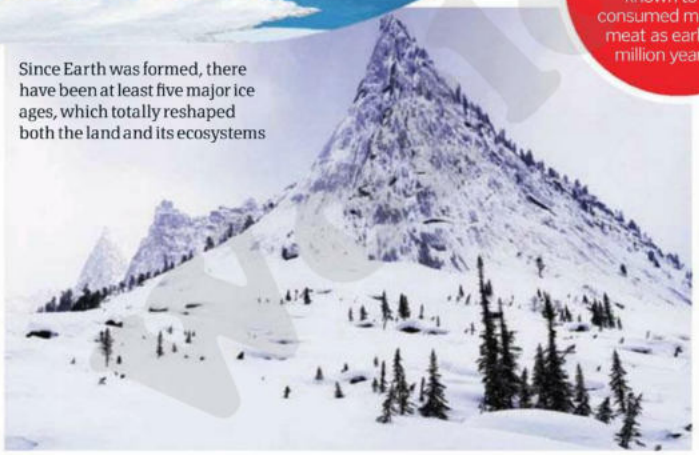
Originating about 2.5 million years ago in the northern foothills of the Himalayas and lasting until 10,000-8,000 years ago, the woolly rhinoceros was driven to extinction by a mixture of the receding ice age and early human predation. Interestingly, recent studies of the species have concluded that for the majority of their evolutionary existence they were confined to steppe environments in continental Asia, yet as conditions became more arid towards the close of the last ice age, they migrated north-eastwards into Europe and Russia.

Mammoth

Almost all species of mammoth naturally migrated, ranging from their origin species in Africa, through the European species and on to North American and Siberian species. During the close of the last ice age, the largest migrations were undertaken by the woolly mammoth, with retreating ice sheets forcing the animals out of North America and deeper into Siberia. A 2008 study estimated climate changes shrank its suitable habitat from 7.7 million square kilometres (3 million square miles) to just 800,000 square kilometres (310,000 square miles).

DID YOU KNOW?

Homo erectus is now known to have consumed mammoth meat as early as 1.8 million years ago.



Since Earth was formed, there have been at least five major ice ages, which totally reshaped both the land and its ecosystems

Amur Tigers 360 left in wild today!

© Julie Larsen Maher/WCS

© Royal British Columbia Museum

Hunting

The spread of human hunters throughout much of northern Eurasia and the Americas, in all likelihood, contributed significantly to the mammoth's decline. A recent dig site in the Ukraine also suggests Neanderthals used mammoth bones for the construction of their homes.

Warming

The Earth went through a warming trend at the start of the Holocene period 12,000 years ago. This caused a vast glacial retreat and rising sea levels that would have severely shrunk the mammoth's typical habitat. Changing vegetation could also have contributed to their decline.

Disease

A more modern explanation, which is backed up by all of the various subspecies becoming extinct in a relatively short time, is by infectious disease. It is speculated the illness could have mutated naturally, or been passed on by prehistoric humans.

ANATOMY OF EXTINCTION:

MAMMOTH

Why did the mammoth die out? Here are a few key reasons...

148m

Torvosaurus

With its name meaning 'savage lizard', the torvosaurus was a fierce predator in the Late Jurassic period and weighed 2.2 tons when fully grown.

65.5m

Tyrannosaurus rex

Arguably the most famous dinosaur of them all, the T-rex reigned over the Earth for 2.5 million years during the Late Cretaceous period. The species met its demise in the K-T extinction event.

10,500BCE

Cave lion

Technically referred to as the Early Middle Pleistocene European cave lion, this species was similar to today's lions, measuring 2.4m (7.9ft) long and bearing large teeth and claws.

"The Syrian elephant, Steller's sea cow, elephant bird, thylacine, quagga, Caspian tiger and western black rhino have all been driven to the brink, and over it, by hunting"

inhabitants. However, on the flipside, when you factor in that the current general scientific consensus states that human-caused activities over the past 200 years – such as deforestation and industrial pollution – have sharply increased global warming through the generation of greenhouse gases, the geo-climate changes typified towards the end of the last ice age are in fact being perpetually fuelled today, exacerbating the natural process.

Artificial extinction

Since the rise of early man, a major cause of extinction has been simply their – and subsequently our – presence on Earth (for a comprehensive breakdown of modern man's activities see the 'Manmade extinction' section on page 22). Hunting, one of the earliest causes – by early humans and later homo sapiens – has caused many of the world's most notable animals to become extinct, a process that is continuing even today. To name but a few, the Syrian elephant, dodo, elephant bird, Steller's sea cow, quagga, thylacine, Caspian tiger and western black rhino have all been driven to the brink, and over it, by hunting.

These types of exterminations were often justified on the grounds of their isolation and singularity, or perceived threat to human habitation. Importantly though, the nature of Earth's ecosystems is very tight knit, with many animals intrinsically linked (eg co-evolutionary species), with each surviving thanks to others' existence. By removing one, you threaten to instigate a knock-on effect in which many other species are forced to rapidly adapt or perish.

Regardless of whether human-caused extinction can ever be justified – our eradication of the small pox virus, for instance, has saved members of many species including our own – today's continued decline of worldwide species re-raises the heart of the matter regarding extinction and how to combat it.

While many may argue that humans hold dominion over all other species, it doesn't make it true, ethically right or something that should be exploited. Not only does each extinction lead to a reduction in a habitat's biodiversity and sustainability, but it impacts the human race and all future generations.

DID YOU KNOW?
The International Union for Conservation of Nature (IUCN) was founded in 1948.

While the nymphargus griffithsi frog is still fairly common in Colombia, its numbers in Ecuador have plunged

Blue-throated macaw
250 left in wild today!

© Greg Hume

ANATOMY OF EXTINCTION: DODO

Why did the dodo die out? Here are a few key reasons...

Homeless

One of the main causes of the dodo's swift extinction was the effect of human-caused habitat loss. The rapid clearing of forests for firewood and building construction drove the dodo into smaller and smaller territories, generating habitat and population fragmentation, which exacerbated the other causes of extinction.

Fearless

Living in complete isolation from any predator for thousands of years, the dodo naturally developed a complete lack of fear towards other animals. Unfortunately, when humans and their pets/livestock settled on Mauritius, their docile nature led them to be easily shot or preyed upon.

Flightless

Due to the abundance of food on Mauritius, the dodo didn't need to travel great distances to feed. As such, with each subsequent generation the species grew in stature and slowly lost its ability to fly. As soon as predators were unleashed on to the island, this became a fatal flaw.

© SPL

10,000BCE

Mammoth

A large form of megafauna, mammoths roamed the Earth for close to 5 million years before largely dying out at the close of the last ice age. However, we know one or two pockets survived up until 4,000 BCE.

8,000BCE

Smilodon

Sabre-toothed tigers were one of the Pleistocene era's most fearsome predators. Its hunting days over modern-day North America were cut short by climate change and prehistoric human predation.

5,000BCE

Irish elk

The largest deer that ever lived, the Irish elk stood over 2m (6.5ft) tall at the shoulders. It is widely accepted that hunting was a major cause of its departure.

EXTINCT IN THE WILD

Extinction is a day-by-day occurrence, with hundreds of species disappearing each year. We select a few species that are no longer alive in their natural environments, or not far off...

Barbary lion

With the last wild barbary lion shot in 1922, today the species is generally considered extinct. A few unverified claims have stated select individuals still exist in private collections.

Seychelles giant tortoise

A populous resident of the Seychelles until the mid-19th century, this giant tortoise today is limited to a small batch held in captivity. One of the creatures, named Jonathan, is over 180 years old.

Scimitar oryx

In the early 19th century the scimitar oryx inhabited the whole of North Africa. However, due to extreme human predation for their horns, the species is now considered extinct in the wild, with no confirmed sighting for 15 years.

Giant panda

The giant panda is currently rated as 'Endangered' on IUCN's Red List. Today, the species is dwindling rapidly due to human-caused habitat loss and low birth rates. While the species is not extinct in the wild, many argue it won't be long.

Mauritius was dodo paradise until the arrival of human settlers

Elephants may prove the key to bringing back mammoths using cloning techniques

BRINGING THEM BACK...

The cloning of extinct animals is a growing field, opening the possibility of reanimating species that have been dead for hundreds, thousands or even millions of years

In October 2000, a team of scientists from the Advanced Cell Technology company announced they were going to attempt to bring back to life the extinct species of Pyrenean ibex (capra pyrenaica pyrenaica). The team was to use nuclear transfer cloning technology – a process in which the DNA from an unfertilised egg is removed and then injected with the nucleus of the desired animal to be cloned (gathered from the last animal to die – a female ibex named Celia) into a host mother for rebirth. The objective of the experiment was to produce multiple ibexes and then return them back to their natural habitat in the Pyrenees.

Unfortunately, despite a Pyrenean ibex being born alive from its surrogate mother, within a short period of time it died as a result of lung defects. Further, the project highlighted a fatal flaw in current cloning technology, in that even if a new female animal could be brought back to life, there would be no male Pyrenean ibexes for the clone to breed with. Beyond this, on a more general level, if species were to be brought back to life that lived millions of years ago – as famously speculated by the film *Jurassic Park* – the environmental (changes to atmosphere composition, for example) conditions of the Earth today would prove a major stumbling block for their adaptation and survival.

Despite this setback, a new international team of scientists from Japan, Russia and America are beginning this year on a project to clone a mammoth from tissue samples retrieved from a carcass excavated from Siberian permafrost. The plan involves the same nuclear transfer cloning process that was used for the Pyrenean ibex, with the resultant embryo deposited into the womb of a modern elephant for the gestation period. Whether or not the project will succeed is still up for debate, however a recent project to clone a rat from frozen cells was successful.

> **"The objective of the experiment was to produce multiple ibexes and then return them back to their natural habitat"**

100BCE

Syrian elephant

Highly prized by Ancient Syrian craftspeople for its ivory, the Syrian elephant was quickly hunted to extinction. Syrian ivory production was at its peak during the first millennium BCE.

~1600CE

Elephant bird

Elephant birds were a family of flightless birds, with the biggest exceeding 3m (9.8ft) in height and weighing 400kg (880lb). Their extinction, again, is believed to have been caused by human predation.

Florida yew

Range: Florida – notably around the Apalachicola River

Assessment history: 1997 – Vulnerable; 2011 – Critically endangered

Population trend: Decreasing

Habitat: Ravines

Threats: Logging, local fauna

Description: Located in a 10sq-km (3.9sq-mi) area of northern Florida at altitudes between 15 and 30m (49 and 98ft), the Florida yew is an evergreen coniferous species that grows to around 6m (20ft) high. It is dioecious, with male and female cones developing on separate plants; it is also poisonous to humans. Logging in the 20th century led to range reduction and habitat fragmentation, initiating a rapid decline of this tree.

Atelopus patazensis

Range: Peru – notably the Pataz province of La Libertad

Assessment history: 2000 – Critically endangered; 2011 – Critically endangered

Population trend: Decreasing

Habitat: Freshwater, bunchgrass and shrubs

Threats: Industrial mining, domestic waste

Description: A small toad endemic to Peru, atelopus patazensis lives in highland environments. Over the past ten years the species has been in steep decline, with mining activities thought to be the prime cause. Studies have shown large quantities of mercury in the region's streams.

Bog turtle

Range: Eastern United States – notably North Carolina, Pennsylvania and Virginia

Assessment history: 1988 – Rare; 2011 – Critically endangered

Population trend: Decreasing

Habitat: Marsh and swampland

Threats: Agricultural drainage, black-market pet trade

Description: Weighing no more than 110g (3.8oz), the bog turtle is a semi-aquatic species first recorded in 1801. It has a slow reproduction rate and is omnivorous. Manmade changes to the turtles' habitat and their popularity on the black market has led to an 80 per cent drop in colonies over the past 30 years.

European mink

Range: Europe – notably France, Spain and Romania

Assessment history: 1988 – Vulnerable; 1996 – Endangered; 2012 – Critically endangered

Population trend: Decreasing

Habitat: River banks

Threats: Habitat loss, hunting, alien invasion

Description: Originally prolific through Europe, this mink now exists only in isolated pockets, with its total range reduced by over 85 per cent since 1850. The European mink is currently threatened by a lethal combination of habitat loss, hunting and competition from the alien American mink.

Blue-throated macaw

Range: Bolivia – notably the Beni savannah

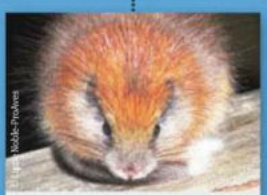
Assessment history: 1994 – Endangered; 2011 – Critically endangered

Population trend: Decreasing

Habitat: Gallery and island forests

Threats: Black-market pet trade, logging, agriculture conversion

Description: A brightly coloured species endemic to north-central Bolivia, the blue-throated macaw is currently one of the most endangered species on the planet, with only 250 individuals left in the wild. Its decline has been caused by several factors, all of them driven by humans.



Red-crested tree rat

Range: Colombia – notably Sierra Nevada de Santa Marta

Assessment history: 1996 – Vulnerable; 2011 – Critically endangered

Population trend: Unknown

Habitat: Upper tropical to lower montane forest

Threats: Unknown – logging and climate change are speculated

Description: With only one confirmed contact in 114 years, very little is known about the red-crested tree rat's habits, leading to a knock-on effect of a lack of knowledge regarding its potential threats. An increase in holiday homes and coffee cultivation in the region are suspected to be two major ones.

IUCN RED LIST

TODAY'S CRITICALLY ENDANGERED

How It Works selects a handful of the latest flora and fauna to be rated as critically endangered on the International Union for Conservation of Nature's Red List of Threatened Species

1681CE

Dodo

Now perceived as an icon of extinction, the dodo was famously hunted and displaced to extinction in the 17th century. They were flightless and super-vulnerable relations to modern-day pigeons.

1768CE

Steller's sea cow

Similar to dugongs and manatees, the Steller's sea cow was a large herbivorous marine mammal in the North Pacific. Just 27 years after its discovery the slow-moving animal was hunted to extinction.

1870CE

Quagga

A subspecies of zebra, the quagga was at one time common in South Africa. It was differentiated from a zebra by its unique head-only stripes, with the centre and rear fading in colour into solid brown.

Adriatic sturgeon

Range: Adriatic Sea – notably off the eastern coast of Italy

Assessment history: 1996 – Vulnerable; 2009 – Endangered; 2011 – Critically endangered (possibly extinct)

Population trend: Decreasing

Habitat: Large rivers/costal seas

Threats: Overfishing (legal and illegal), habitat loss

Description: This large type of sturgeon is rarely seen in the wild and, in light of an estimated population decline of over 80 per cent in 60 years, is listed as 'possibly extinct' on the Red List. From most recent figures, it is thought there are no more than 250 Adriatic sturgeon left, with most in the area of the Po River.

Blue-crowned laughingthrush

Range: China – notably the Jiangxi province

Assessment history: 1988 – Not recognised; 2006 – Least concern; 2011 – Critically endangered

Population trend: Increasing

Habitat: Forest and shrubland

Threats: Black-market pet trade, habitat destruction

Description: With an estimated 240 left in the wild, the blue-crowned laughingthrush is an incredibly rare resident of China's Jiangxi province that nests commonly in camphor and maple trees. The small bird's severe decline is largely due to trapping for the black market.

Blue-eyed black lemur

Range: Madagascar – notably the Sahamalaza Peninsula

Assessment history: 1986 – Endangered; 2011 – Critically endangered

Population trend: Decreasing

Habitat: Primary and secondary tropical, sub-humid forest

Threats: Slash-and-burn agriculture, logging, hunting, black-market pet trade

Description: A species of true lemur, the blue-eyed black lemur is commonly found in groups of between seven to ten individuals, and its diet varies from fungi to fruits. Over the past 100 years human logging and construction have cleared almost the species' entire native habitat, and this is the lemur's greatest threat.

Black rhinoceros

Range: Africa – notably Angola, Kenya, Namibia, South Africa and Tanzania

Assessment history: 1986 – Endangered; 2011 – Critically endangered

Population trend: Increasing

Habitat: Desert, savannah and forest

Threats: Poaching

Description: Adult black rhinos grow up to 1.8m (5.9ft) high at the shoulder and 3.8m (12.5ft) in length. Its twin horns are made of keratin and can grow to over 1m (3.3ft) in length. The species is primarily under threat from poachers. Since 1960 their numbers have decreased by a staggering 97.6 per cent.

Siau Island tarsier

Range: Indonesia (Siau Island)

Assessment history: 2011 – Critically endangered

Population trend: Decreasing

Habitat: Primary and secondary mangrove forests

Threats: Geo-climate change, habitat loss, hunting

Description: The Siau Island tarsier is one of Indonesia's rarest creatures. Linked to other Eastern tarsiers, the species is only found on Siau Island, which is dominated by a large active volcano. Asides from the obvious volcanic threat, the population is currently most threatened by human dwelling expansion as well as being hunted for food.

Chinese water fir

Range: Vietnam/China – notably Fujian, Guangdong and Sichuan provinces

Assessment history: 1997 – Rare; 2006 – Endangered; 2011 – Critically endangered

Population trend: Decreasing

Habitat: Floodplains and deltas

Threats: Agricultural conversion, logging

Description: A species that is intolerant of competition, the Chinese water fir traditionally was widespread throughout China and Vietnam. Today, however, only 250 or so remain in the wild, with persistent generation-on-generation decline driven by insensitive agricultural clearing and illegal logging.

© NASA

1936CE

Thylacine

The largest-known carnivorous marsupial of the last 200 years, the thylacine (or Tasmanian tiger) lived in Tasmania until a mixture of human disease, hunting and habitat loss led them to be wiped out.

~1960CE

Caspian tiger

Throughout the 19th century a resident of forests around the Caspian Sea, by 1970 the Caspian tiger had been hunted and displaced to extinction. The last known confirmed sighting was in 1958.

2000CE

Pyrenean ibex

The last ever naturally born Pyrenean ibex was found dead on 6 January 2000. However, in 2009 scientists cloned a female ibex that, while born alive from a host mother, died after several minutes.

MANMADE EXTINCTION

Despite many species facing a wide range of natural threats, the biggest of them all is that posed by homo sapiens

An example of a snare that poachers use to trap mountain gorillas

2x © Mountain Gorilla Veterinary Project

Much of the land that was once lush rainforest in Haiti is now barren due to deforestation

ILLEGAL LOGGING

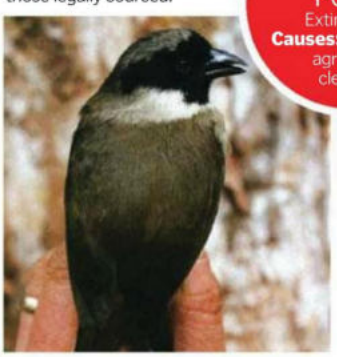
From Europe to Asia, illegal logging is decimating protected and unprotected environments alike, sacrificing Earth's most diverse ecosystems

Illegal logging is estimated to cost nations worldwide in excess of $10 billion annually. That, however, is the least damaging consequence. More importantly, the mass destruction of Earth's forests and jungles leads directly to large-scale habitat loss for a plethora of species.

What is arguably most shocking about this form of human-made extinction is that, as of 2012, it's estimated that more than 50 per cent of all illegal logging is done in the world's most environmentally vulnerable regions. From the exotic Amazon Basin through to the diverse islands of Southeast Asia, the percentage of illegally harvested logs far outweighs those legally sourced.

Of all areas of concern, tropical rainforests are receiving the most attention, both from illegal loggers and from conservationists. Why is this? Of approximately 16 million square kilometres (10 million square miles) of tropical rainforest habitat that once existed on Earth, today less than 9 million square kilometres (3.5 million square miles) remain. Indeed, the current rate of tropical deforestation lies at 160,000 square kilometres (62,000 square miles) a year, or one per cent per annum. This is highly worrying as tropical rainforests are home to over 50 per cent of all of the planet's species. In fact, there is often more than 43,000 species of plant, animal and insect found in a single hectare.

NOW EXTINCT
Po'ouli
Extinct 2009
Causes: Habitat loss, agricultural clearance



POACHING

Fuelled by human greed, both for exotic foods and for money, many of Earth's most endangered species are being trapped and killed every day

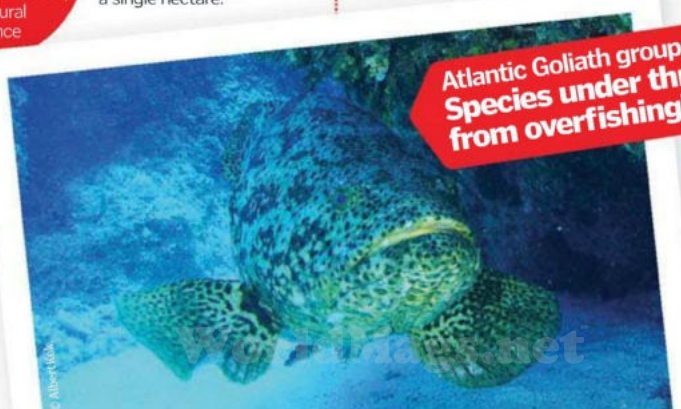
The Victorian notion of humans being the God-given rightful rulers of Earth and its animals, despite being largely quashed today, has sadly permeated into the 21st century, leading to small but fanatical areas of horrific hunting. Driven by a desire of wealth and pleasure, critically endangered species of all types are being marked for death or capture by poachers who, asides from conservationist institutions, face little opposition.

While the images on this page are unsettling, what is most disturbing is the numbers that run underneath them. Madagascar's lemurs – which are considered a delicacy in many of the nation's restaurants despite being both protected and endangered – are bought dead by middlemen for roughly 35 pence (53 US cents) per animal. These are then sold on to the restaurants for about £2.70 ($4.20). Mountain gorillas – again a critically endangered species with less than 700 left in the wild – can fetch anywhere between £2,500 ($4,000) dead to upwards of £25,500 ($40,000) alive. Even parts of animals are highly desired, with bear paws costing £32 ($50) for four, shark fins £250 ($400) per pound and rhino horns selling for up to £62,000 ($97,000) per kilo.

As of 2012, poaching is driving well-known species such as the black rhino, Siberian tiger, mountain gorilla and Siau Island tarsier to the brink. And it's a vicious circle, with every death inflating their black-market price even further and, as a direct consequence, making them even more desirable to poachers.

NOW EXTINCT
Western black rhinoceros
Extinct 2011
Cause: Poaching

Tropical birds are extremely popular pets but as they aren't adapted to life in a cage many die from stress



Atlantic Goliath grouper
Species under threat from overfishing!

© Albert Kok

NOW EXTINCT
Golden toad
Extinct 2004
Causes: Habitat loss, global warming

AGRICULTURE AND CONSTRUCTION

As human populations boom there's an ever-greater demand for dwellings and farmland, and it's natural habitats that are paying the price

A primary cause of species population decrease is habitat fragmentation – the emergence of discontinuities in an animal's preferred environment. This inevitably leads to the species population breaking up, thereby isolating small groups of animals/plants in tiny islands of habitable environment. Consequently, there is significantly less diversity in food sources and potential mates, which decreases the chances of survival and reproduction considerably.

The two main causes of habitat fragmentation are both human caused and are agricultural clearance and rural development. The former is epitomised by the slash-and-burn process used to clear rainforest areas so that the planting of crops can proceed. The latter is typified by the construction of roads, factories and towns within areas of intense biodiversity. The two causes are commonly linked, with new settlements built to help deal with a rising population of humans, and then agricultural areas established in the locale to help feed them.

An aerial shot of Bolivian soy bean plantations fragmenting the natural forest

BLACK-MARKET PET TRADE

Each year thousands of animals are sold through the illegal pet trade regardless of their suitability

The other way to monetise poaching is through the sale of animals in the global black-market pet trade, an industry that generates £20bn ($32bn) per year. To put the scale of this in perspective, in 2002 it was estimated the black-market pet trade was the second-most profitable illegal business in the world, with only the international drugs market topping it.

This may sound fanciful, but when you look at the size of pet markets across nations ranging from Brazil to China, and then partner that with the fact that Europe and the US are the two biggest importers of wildlife and wildlife 'products' in the world, and it's easy to see why conservation organisations are frequently raising the issue with policy makers.

Specific stats are equally scary. Between 1996 and 2007 635 tons of wildlife, with a total of 181,670 individual animals, were confiscated in transit to and from Vietnam. From 2001-05, over 11,000 specimens were seized in Central America. And, lastly, almost entirely due to poaching for the global birdcage black market, the blue-throated macaw's wild population now rests at 250 individuals and it has recently been uprated to Critically endangered on IUCN's Red List.

Interview Jean-Christophe Vié

How It Works speaks to the deputy head of the IUCN Species Programme about its conservation projects and what we can do to help

HIW: Could you talk about the Save Our Species (SOS) initiative?
JCV: We launched the SOS in 2010. The basic setup is that the World Bank supplies the funds and we do the work. Of course the main objective is to fund conservation on the ground but the second objective – one which appeals to our partners – is to mobilise additional funding, particularly from the private sector. We don't want to divert existing funding from elsewhere that is going to NGOs (non-governmental organisations), but we try to join forces to mobilise new funding and to present something that would attract mainly corporate organisations but also governments and foundations.

So that is one reason why in this first list of projects just announced we have funded a lot of charismatic species. However while we have some well-known species, they are not all so. What we want is stories that we can easily communicate to the rest of the world. We aim to explain why nature and life are important for everyone. These first 23 projects are the result of the first open call for proposals, which went worldwide. We received 400 proposals and had to whittle this down to just 23.

HIW: How seriously are national governments taking conservation?
JCV: They are and they aren't. It depends. In France, for example, there is a presidential campaign currently being run in which the candidates – just to please people – are ready to relax anything to do with conservation. From the hunters to the farmers – everything. Nature is not something that is recognised the way it should be. If politicians wanted to [do something] they could. They have all the facts; they know that nature is the largest industry in the world. If they had to choose between ten jobs and ten acres of forest, the jobs win; that is the political game.

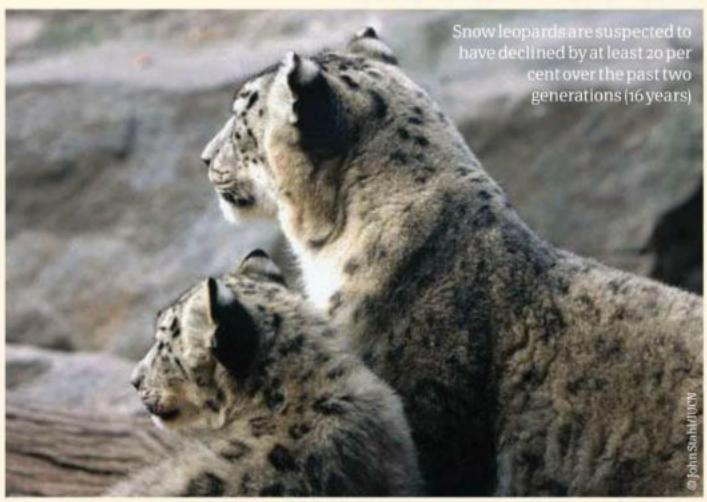
For some perspective, it's worth looking at the world economy and the banks. The investment to rescue banks compared with the investment to rescue our planet – which there is nothing more important than – is ridiculous. Still, you get people saying that it costs this massive amount of money to conserve this species or that area, but it's not a massive amount of money – it is peanuts in comparison.

HIW: How can HIW readers get involved in conservation?
JCV: There are many different ways to get involved in conservation. There are many organisations absolutely everywhere that they could contact and support.

More locally, there are many things you can do just in your backyard though – for instance, there are birds and butterflies and many other animals you can look after. Everyone is a consumer too so you can decide not to buy products from one company and instead buy them from a greener enterprise. I think that green companies are not yet rewarded enough.

You can also vote for people who want to change things – politicians who want to preserve nature and life, as there is nothing more important than that.

SOS
SAVE OUR SPECIES



Snow leopards are suspected to have declined by at least 20 per cent over the past two generations (16 years)

© John Stahl/IUCN

Welcome to... ENVIRONMENT

Following our epic 12-page feature on extinction this issue, the Environment section is doing something of a world tour. We kick off in the Arctic, where we learn how an entire ocean can turn to ice, before moving to warmer climes to find out about the curious anteater (in South America) and Earth's biggest bloom (in Southeast Asia).

26 Tar pits

27 Largest flower

30 Anteaters

24 Arctic sea ice
26 Tar pits
26 Windchill
26 How worms burrow
27 Biggest flower
30 Anteaters

LEARN MORE

How the Arctic Ocean freezes

It's difficult to imagine such a huge expanse of water freezing solid, so how is it possible?

Arctic sea ice is that which forms on the Arctic Ocean during the winter months. Pure water, which contains no other molecules, substances or impurities, freezes at 0 degrees Celsius (32 degrees Fahrenheit). The world's seawater, on the other hand, contains around 3.5 per cent dissolved minerals and salts. This additional material lowers the freezing point of the seawater to around -2 degrees Celsius (28.4 degrees Fahrenheit) because the freezing point depends on the number of molecules present in a solution, as well as the type of molecule(s).

During the winter months, when the air temperature in the Arctic starts to fall dramatically, a deep layer of seawater begins to develop minuscule ice crystals; this slushy water is called frazil ice. A further drop in temperature causes the frazil ice to thicken. Pockets of salty slush accumulate until they become so heavy they start to sink. This leaves the top layer of icy crystals with significantly less salt content. The freezing point of this surface water therefore becomes higher and the falling temperatures enable the crystals to solidify into pack ice.

This pack ice grows to become one huge floating sheet (made up of many smaller floes), the thickness and coverage of which varies over the year, but reaches its peak in March. During the warmer summer months, meanwhile, the ice begins to retreat and break up, reaching its lowest extent around September.

THE STATS
ARCTIC TRIVIA

AREA BY WHICH ARCTIC SEA ICE IS RECEDING PER DECADE **10%**

SEAS AROUND THE ARCTIC OCEAN **8**

NUMBER OF NATIVE PEOPLES **>30**

POPULATION **~4 million**

ANNUAL PRECIPITATION **50cm**

COLDEST TEMP ON RECORD **-68°C**

DID YOU KNOW? *At its current rate of decline, it's predicted there will be no Arctic sea ice left by the end of the century*

A satellite shot of sea ice floes and icebergs off the coast of Antarctica

Learn more

Follow this handy QR code for a quick link to a 'cool' NASA video on HIW Daily about the importance of Arctic sea ice on world climate.

© SPL

How polar ice affects the world climate

Sea ice at the poles is important because it influences the weather across the entire planet. The ice acts like a mirror, deflecting the Sun's rays back into the atmosphere. As the ice melts, more of the 'dark' ocean beneath, capable of absorbing the Sun's heat, is exposed. When the Arctic is frozen, warmer water entering from the Pacific or Atlantic begins to cool, becoming dense and sinking. This displacement of water drives the circulation of Earth's oceans, affecting weather and conditions throughout the world. So, in many respects, the amount and extent of Arctic sea ice is critical to the global climate.

High reflection
The white sea ice cover acts like a mirror, reflecting the Sun's rays back out to space, preventing the sea from heating excessively.

Sea exposed
As the ice melts, there is more dark seawater to absorb sunlight, which further melts the ice.

4X © NASA

Low reflection
The more sunlight absorbed by the seawater, the more the ice melts until, eventually, significantly less light is reflected back into space.

"Once consumed by the tar pits, the bones of the dead animals did not decompose"

What are the La Brea Tar Pits?

Discover why California's tar pits are among the richest and most well-known sites for ice age mammal bone excavations

Their preserving nature makes tar pits some of the best fossil museums on the planet

©SPL

The viscous tar lakes known as Rancho La Brea in California have yielded some of the most numerous and insightful fossilised remains ever discovered on Earth. While hundreds of years ago, locals thought the bones excavated from the pits were those of cattle and native wildlife, it now transpires that the remains are in fact those of many million plants, creatures and megafauna dated between 10,000-40,000 years old from the Pleistocene epoch. Specimens discovered include sabre-toothed cats, dire wolves and mammoths.

Millions of years ago, when Los Angeles was underwater, dead marine life and sediments built up on the seabed. As more and more sediment piled up – not to mention the immense weight of the overlying ocean – the layers of carbon-rich organic matter became increasingly compressed and heated. In an environment starved of oxygen this caused the material to become fossil fuels, such as crude oil (petroleum).

Once the sea receded, the tar at La Brea began to form. Petroleum deposits far below the surface were forced to bubble up to the surface by underground pressure. Gradually, as the petroleum evaporated from the surface, large pools of thick, sticky asphalt, or pitch, were left behind.

The land was capable of sustaining vegetation, and plants and even trees took root here, enticing animals and insects to venture out over the pits. This is what led to many prehistoric creatures, large and small, becoming trapped in the sticky lakes.

Once consumed by the tar pits, the bones of the dead animals did not decompose, but instead were perfectly preserved, producing some of the most impressive fossilised remains ever to be found.

ON THE MAP

Tar pits around the globe

1 Tierra de Brea, La Brea, Trinidad and Tobago
2 Lake Bermudez, Estado Sucre, Venezuela
3 La Brea Tar Pits, Los Angeles, USA
4 McKittrick Tar Pits, McKittrick, USA
5 Carpinteria Tar Pits, Carpinteria, USA

What is the wind-chill factor?

Why does this phenomenon make it feel colder than it really is?

The wind-chill factor describes the rate at which your body loses heat due to wind and low temperatures. When it's chilly outside you will of course feel the cold. However, when fast-moving air (ie wind) blows across your exposed skin you will feel even colder. This is because as wind speed increases, the rate at which heat is carried away from the body also increases, first causing an external temperature drop, then later – and more dangerously – a reduction in internal body heat.

The NOAA's National Weather Service's windchill index shows the serious implications. For example, if the temperature is -18 degrees Celsius (0 degrees Fahrenheit) and the wind speed is 24 kilometres (15 miles) per hour, the wind-chill factor would be -28 degrees Celsius (-19 degrees Fahrenheit) and human skin would experience frostbite in just 30 minutes.

Worms do a stellar job of revitalising soil, helping plants to grow

How worms burrow

Earthworms are vital as their tunnels aerate the soil while their waste provides it with nutrients

In order to tunnel through soil, an earthworm must be pretty tough despite its soft and delicate outer appearance. The body of the worm is made up of many muscular ring-like segments called annuli, which look like grooves on the outside of the creature's body. It expands and contracts these segments in a wave-like sequence, meaning that different segments contract at different times, to draw itself through the earth.

Additionally, each segment is covered in minuscule thorn-like projections called chaetae, which it uses to grip on to the soil and leaf litter. When a segment contracts it bulges, causing the chaetae to catch on to particles of earth. Once this segment is stuck firmly against the soil, the worm can then extend its other segments to haul itself along.

RECORD BREAKERS
TALLEST PLANT

115.54M

HYPERION THE COAST REDWOOD

The world's tallest living tree is 115.54m (379.1ft). Known as Hyperion, this coast redwood (sequoia sempervirens) was measured by climbing to the top and dropping a tape measure.

DID YOU KNOW? *Another plant native to Sumatra that's also known as the corpse flower is the equally stinky titan arum*

How the rafflesia grows

Though the rafflesia has a relatively short life of about a week, it can be several years in the making. First, parasitic filaments of fungus-like tissue penetrate the vascular tissues of the stem/root of the host vine. Between a year and a year and a half later, the rafflesia then begins to develop outside the host vine as a tiny bud. For nine months this bud swells into a growth that eventually bursts out of the host's stem or root. The growth will continue to expand until it looks like the head of a large brown cabbage. The rafflesia usually blossoms overnight, producing the smelly, record-breaking bloom as the petals unfurl.

World's biggest flower

Discover the enormous corpse flower, and find out why this is one of the heaviest, rarest and smelliest blooms found on Earth

Rafflesia arnoldii, with its massive one-metre (3.3-foot)-diameter bloom, is the largest individual flower yet found on the planet – usually in the tropical rainforests of Indonesia.

The plant has neither a stem, roots, nor leaves, and it doesn't even contain chlorophyll, which means it's incapable of photosynthesis to produce food for itself. Instead this endoparasitic plant survives by growing inside the damaged stems or roots of a host plant, a kind of grape vine known as tetrastigma, and draining nourishment from this.

Once the flower is ready to bloom it bursts out of the host to reveal a vibrant yet foul-smelling blossom. And it's this odour of rotting flesh that justifies rafflesia arnoldii's other, more familiar moniker: the corpse flower. This, together with its distinctive red-and-white polka-dot appearance, attracts carrion flies, which help to pollinate the giant flower.

The statistics...

Rafflesia arnoldii (corpse flower)

Genus: Rafflesia
Habitat: Rainforests of Southeast Asia
Diameter: 1m (3.3ft)
Weight: 10kg (22lb)

1 WEB HOST
MISSABLE OFFERS

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"The giant anteater is a solitary creature and, aside from mothers and babies, they are rarely found in pairs"

The statistics...

Giant anteater

Genus: Myrmecophaga tridactyla
Class: Mammal
Length: 2m (7ft)
Tongue length: 0.6m (2ft)
Diet: Carnivore
Weight: 20-50kg (44-110lb)
Life span: 14 years (wild), 26 years (captivity)
Status: Threatened due to habitat destruction

Fur
The anteater's fur is long, coarse and dense to help protect it from biting insects.

Eyes
Anteaters are practically blind so they make up for this with their extra-sensitive sense of smell.

Tail
The giant anteater's massive bushy tail is almost as long as its body. The tail is useful for balance if the anteater rears up to attack with its front paws. Also they sleep on the ground and use their tail to keep warm and remain hidden.

Claws
Anteater forearms are very powerful with five deadly claws on each paw, the inner three of which on the front feet are especially long and sharp. This helps them penetrate the walls of termite fortresses.

Giant anteaters

They have no teeth, walk on their knuckles and take life at their own pace, so how do they survive?

As is to be expected, the giant anteater, native to the savannas of Central and South America, is the largest of its kind. This bizarre-looking mammal is designed specifically for feeding on ants and termites, and a number of anatomical features enable them to do this with great skill. Powerful forearms and long, sharp claws help the anteater to tear into anthills and termite mounds so they can insert their long, tapered snouts to get at the insects. They are always careful not to destroy the nest so as to preserve the feeding spot for another meal.

While the claws are mainly used for breaking into anthills, they can also perform a defensive role. When attacked by their main predators, which include large cats like jaguars, anteaters have been known to lash out and kill these hunters. While giant anteaters are slow, terrestrial creatures that walk around on their knuckles to protect the claws, smaller species of anteater are arboreal and spend a lot of time in trees looking for insects.

The giant anteater is a solitary creature and, aside from mothers and babies, they are rarely found in pairs or groups. Anteaters usually give birth to a single cub, who will then ride around on the mother's back for up to a year, clinging on to the thick, coarse fur. Because they live on a diet of ants, which have relatively limited nutritional value, the giant anteater does what it can to conserve energy: it has a very low metabolic rate and will sleep for up to 15 hours every day. They move around the grasslands very slowly – they cannot run – and keep their body temperature low, sometimes as cool as 32.7 degrees Celsius (90.9 degrees Fahrenheit).

An anteater's sense of smell is so acute it can detect the species of ant or termite before breaking into a nest

1. SUPER-SLOW

Sloth

This nocturnal rainforest dweller hangs in trees by its large, powerful claws, eating vegetation. They move very slowly, and can spend a year in one tree.

2. ARMOURED

Armadillo

Another insectivore, the armadillo has hard, leathery plates on its back, head and sides. It also has the ability to hold its breath for several minutes when digging.

3. EDENTATE

Anteater

Anteaters, sloths and armadillos are all members of the xenarthra superorder. In the past, they were grouped as the edentata – meaning toothless – but only the anteater is actually toothless.

DID YOU KNOW? *Surrealist artist Salvador Dalí had a pet anteater which he used to take for walks*

Anteater anatomy

Tongue

Inside the snout is that incredibly long, ant-slurping tongue. It's covered in sticky saliva and tiny back-facing spines (filiform papillae) to help snag lots of bugs.

Snout

While anteaters only have small mouths, the elongated snout can reach lengths of 45cm (18in). Because it's hollow, the snout is the ideal shape for sucking insects into the mouth. The tip of the snout is very sensitive, helping it probe inside tiny passageways.

Eating ants

Although they have poor eyesight, anteaters have a very keen sense of smell for sniffing out insects, which include ants – of course, termites, grubs and other small insects.

Once an anthill is located the animal uses its strong claws to rip into the prey's lair, making room to insert its long snout. Because some ants can sting and bite, mealtime is a fast and furious affair and the anteater has adapted techniques for licking up ants as quickly as possible. Each feast lasts about a minute before the anteater moves on to the next location.

Inside the anteater's long snout is an even longer tongue, which can protrude up to 60cm (24in). The tongue is covered with sticky saliva produced by extra-large glands and thousands of tiny back-facing spines known as filiform papillae to ensnare the bugs. When the snout enters an anthill the tongue rapidly flicks back and forth up to 150 times per minute, searching for ants. Because it doesn't have teeth, the anteater then crushes the insects against the roof of its mouth with its powerful tongue before swallowing.

Every day an anteater can consume between 30,000 and 35,000 ants, which is necessary for them to obtain enough nutrients. While ants may contain relatively high levels of protein and low levels of fat, their nutritional value for the giant anteater is low, so in order to conserve energy they move slowly and maintain a cool body temperature.

Giant anteaters can sleep for up to 15 hours a day

Meet the family

While the giant anteater is terrestrial, other types are known to venture into the treetops

© Mikhaile Reback

SILKY ANTEATER

Also known as pygmy, dwarf or two-toed anteaters, silky anteaters are the smallest and most shy species in the family. They are arboreal, which means they spend most of their time up in the trees – in fact, they're rarely ever seen on the ground. To help them get around in the treetops they have strong prehensile tails that can grip on to things; they use them to swing from branch to branch and even from tree to tree. They have much shorter snouts than the other species and soft golden fur.

Tamanduas live from southern Mexico down to northern Argentina

TAMANDUA

Tamanduas are sometimes known by other names, such as collared or lesser anteaters. This species is semi-arboreal, which means they spend time up in the trees but also come down for a look around on the ground now and then. Again, when in the trees a prehensile tail comes in very handy. There are northern and southern tamanduas; the former variety is distinguishable not only by its more northerly location, but also because of the distinctive black V-shaped marking that's located on its back.

Welcome to... TECHNOLOGY

From lifesaving medical equipment (defibrillators) to the crime-busting tech cracking down on cash forgerers, through to the latest wave of smarter, tougher and more powerful cameras, we've got it all this month – and a lot more!

34 Jukeboxes

38 PS Vita

41 Defibrillators

32 Counterfeit money
34 Jukeboxes
34 Waterjet cutters
36 Evolution of... printers
38 PlayStation Vita
40 Clothes dryers
40 Surround-sound tech
41 Defibrillators
42 Next-gen cameras

LEARN MORE

Counterfeit money

We take a look at some of the security measures used to put an end to fake currency

Counterfeit money has been around for thousands of years – indeed as long as legitimate currency. From Roman times to modern society, fake money has forever been a problem. Printing and distributing bogus cash has always carried a high punishment and, while the death penalty is unlikely to be used for this crime today, a counterfeiter is still likely to receive a hefty prison sentence.

It is estimated that during the American Civil War, one-third of all currency in circulation was fake, paving the way towards new counterfeit measures to ensure fraudulent notes could not enter circulation. The introduction of a national currency in the USA in the 19th century helped a great deal in clamping down on phoney money, but it did not eradicate it. Tackling fake currency is an extremely difficult process, and over the years various methods have been adopted to detect ever-improving forged notes.

Modern banknotes employ a variety of security measures to ensure that they cannot be replicated easily. Most governments around the world use microprinting, holograms, UV-lit text and more to prevent fraudulent notes entering circulation. However, as long as currency continues to be used, it's unlikely that counterfeiting will stop.

UK £10 FRONT

Print
UK banknotes are printed on special paper that has raised print in certain areas, like the words 'Bank of England'.

Quality
The print quality of the letters is sharp and defined. If the edges of letters and numbers are blurry then you've got a fake.

Hologram
UK banknotes have a hologram that, when tilted, switches between a picture of the goddess Britannia and the value of the note.

Watermark
Hold the note up to the light and the Queen's portrait will appear as a watermark image.

BACK

Microprinting
Since 1990 US bills have carried tiny, crisp writing that is almost impossible to copy on fake bills. On $10 notes this reads 'USA TEN', and so forth for other denominations.

Glow
When under a UV light, the security thread will glow a certain colour. For the $10 bill, the thread glows orange.

"It is estimated that during the American Civil War, one-third of all currency in circulation was fake"

$69.8M

GREATEST BANK HEIST

The largest amount stolen from a bank is $69.8m (£38.6m) from the Banco Central in Fortaleza, Brazil. The robbers dug a tunnel under the bank in 2005 and mostly remain at large.

DID YOU KNOW? *The first paper currency was developed during the Tang and Song dynasties in seventh-century China*

Money-forging countermeasures

How can you tell if your banknote is genuine?

BACK

Metal
On the back of British notes is a dotted metal thread, which will appear as a continuous dark line when held up to the light.

Ultraviolet
Shine a UV light on a UK banknote and its value will appear in bright red and green.

Microletters
The value of the note, in this case £10, is written in tiny lettering beneath the portrait of the Queen.

Ridges
The portrait on the bill has raised ridges that cannot be reproduced by counterfeit printers easily.

Ink
Tilting the bill will reveal colour-shifting ink. Old bills would turn from green to black, but more recent ones change from copper to green.

Strip
A security thread runs from the top to the bottom of the note which will show the text 'USA' and the denomination of the bill when held up to the light.

Watermark
If the bill is held up to the light, it will show a watermark of the person whose portrait is on the bill. For the $10 bill, this is the first secretary of the treasury, Alexander Hamilton.

USA $10 FRONT

HISTORY OF MONEY

Around 600 BCE the Greek region of Lydia was the first to use coins to represent money, which sparked a wave of forgeries involving the mixture of base metals with gold or silver. In the seventh century China made the world's first paper currency with wood from mulberry trees, and attempted to prevent counterfeiting by protecting mulberry forests with armed guards and sentencing forgers to death. In the USA, a national currency was adopted in 1863 and, two years later, the Secret Service was tasked with countering forged money. In 1996, the US introduced new standards for paper cash, like microprinting, to prevent phoney notes being produced. However, counterfeiting remains a big problem. In 2009 the Bank of England revealed that, despite anti-forgery measures, 566,000 counterfeit notes and up to 40 million £1 coins were in circulation in the UK.

Iodine pen

A counterfeit detector pen contains an iodine solution that, when applied to the fibre-based paper used in legitimate notes, remains totally transparent.

In contrast, many forged notes are made from a wood-based paper containing starch. When this comes into contact with the iodine solution it turns brown or black, instantly identifying a fake note.

"Water jets out at a speed of approximately Mach 3; that's 3,676km/h (2,284mph)!"

Classic jukeboxes explained

Combining the traditional Fifties jukebox look with the convenience and quality of CD technology

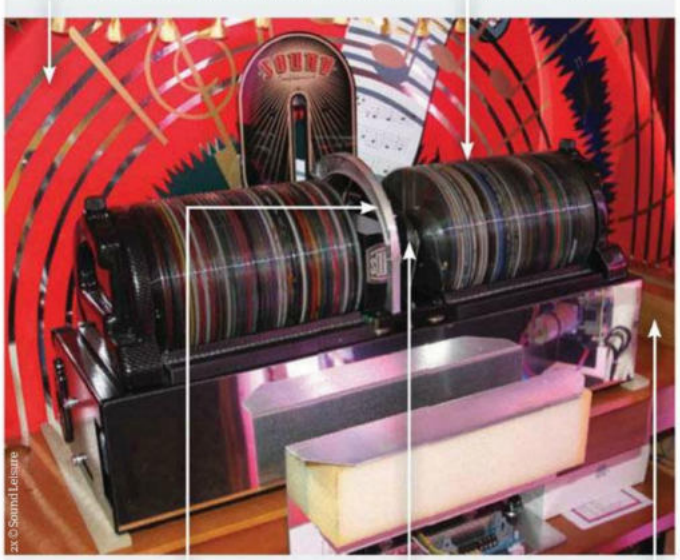
This type of jukebox, with a 21st-century inner mechanism, holds 80 compact discs (CDs) stacked horizontally on a slotted rack. When switched on, the pick-up mechanism runs on a track to the end of the rack, and then a sensor sends it 40 spaces to the centre of the rack. After a CD or song is selected on the panel of the jukebox, or via a remote-control unit, a location wheel on the pick-up mechanism sends it along its track to the correct CD location.

The pick-up mechanism lifts the selected disc, takes it back to the centre of the jukebox, and drops it down to the playback head. The CD playing head will scan the number of tracks on that disc and play the one that was selected. Once the track has finished the CD is lifted and returned to its original slot and the selection process is ready to start all over again.

Inside a CD jukebox

Domed top
The 'bubbler' top is styled after the classic 1946 Model 1015, which reflects the golden age of jukebox design.

CD rack
80 CDs are stacked vertically ready to be selected.

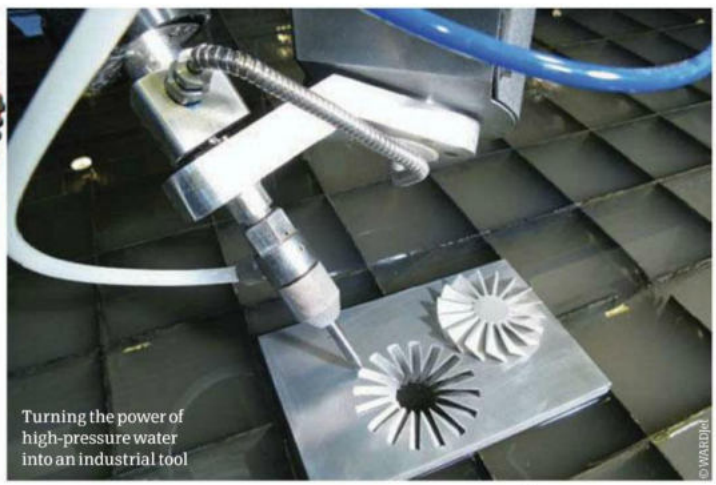


2x © Sound Leisure

Pick-up mechanism
A notched belt drive sends this along its track to select a CD. A location wheel that sends out a pulse every time it passes each CD slot guides it to the correct position.

Playback
The CD is lowered into the playback mechanism. This clamps the disc in position, scans it and plays the requested track.

Cabinet
A loudspeaker dominates the space below the bubbler top. Decorative tubes on the outside of the cabinet contain methylene chloride that is heated to generate a gas that creates a bubble effect.



Turning the power of high-pressure water into an industrial tool

© WARDJet

How can waterjet cutters slice through steel?

The amazing tech that enables water to accurately cut both soft and hard materials

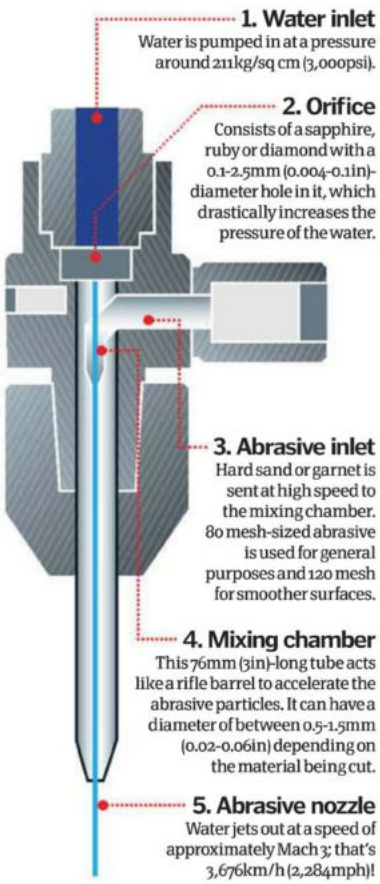
Waterjet cutting can be used to slice through most materials and is a process that does not give off hazardous vapours or waste.

Intensifier or direct drive pumps get the water to the high pressure needed for cutting. The more powerful intensifier pump uses hydraulic oil pressurised at 211 kilograms per square centimetre (3,000 pounds per square inch) to drive a piston biscuit/plunger. This pushes a flow of filtered water that is intensified by 20 times to 4,218 kilograms per square centimetre (60,000 pounds per square inch).

Pure waterjets are used to cut card, nappies and soft materials. The velocity of the water from the jet, rather than the water pressure itself, erodes the microscopic grains of the material using this technique.

Abrasive waterjets, on the other hand, incorporate a rough substance like sand that is accelerated by the water to erode the material, which can include metal, stone or ceramics.

The simplest variety of waterjet machine tools are stationary and cut the material fed into them much like a bandsaw. The more complex programmable five-axis machines, meanwhile, can cut composite materials in three dimensions.



1. Water inlet
Water is pumped in at a pressure around 211kg/sq cm (3,000psi).

2. Orifice
Consists of a sapphire, ruby or diamond with a 0.1-2.5mm (0.004-0.1in)-diameter hole in it, which drastically increases the pressure of the water.

3. Abrasive inlet
Hard sand or garnet is sent at high speed to the mixing chamber. 80 mesh-sized abrasive is used for general purposes and 120 mesh for smoother surfaces.

4. Mixing chamber
This 76mm (3in)-long tube acts like a rifle barrel to accelerate the abrasive particles. It can have a diameter of between 0.5-1.5mm (0.02-0.06in) depending on the material being cut.

5. Abrasive nozzle
Water jets out at a speed of approximately Mach 3; that's 3,676km/h (2,284mph)!

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Computer printers

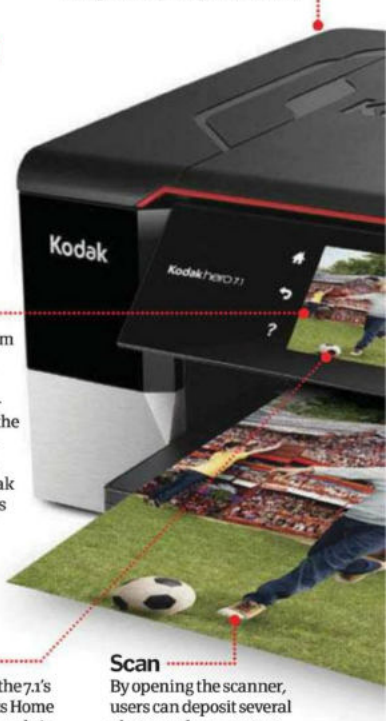
Printers have totally transformed since the Fifties, delivering faster publication speeds and a raft of clever new features

Since English inventor Charles Babbage created the first mechanical computer printer in 1849 – which was used to print the results of calculations from his Difference Engine – a multitude of technologies have been developed off the back of it, all chasing the ideal of the perfect print.

While further mechanical printers were designed and manufactured throughout the late-19th and early-20th centuries, the transition from purely mechanical to mechanical-electrical systems did not arise until the early-Fifties. It was at this point that the first high-speed, non-fluid printer was made by Remington Rand for use with the UNIVAC computer – the first to be commercially produced in the USA.

This was almost immediately followed by two new printing mechanisms – dot matrix and dye sublimation – entering the mainstream market. Dot-matrix printers work by impacting sheets of paper with tiny metal rods, with an inked ribbon sandwiched between the two. Each rod is driven forward by a tiny electromagnet (or solenoid) and, along with the horizontal/vertical movement of a print head, allowed characters to be generated out of a series of impacted dots. Dye-sublimation printers, on the other hand, work by transferring dyes held in coloured cellophane ribbons onto a material through controlled heating. The term sublimation is used as during the printing process the held dye transitions between a solid state to a gas without passing through a liquid stage.

While dot-matrix and dye-sublimation printers are still used today, they are much more limited. This is due to the invention of both laser and inkjet printers, which offer faster and higher-fidelity results – the former first entering the market in 1977. Laser printers, such as the Xerox 9700 – which was the first to be commercially available, work by a process called xerography, which was originally demonstrated by American inventor Chester Carlson in 1938. Xerography is a dry printing technique (ie chemicals are not used) where a negative image is formed of the desired print via the use of resinous powder (toner) on an electrically charged drum. The powder sticks to the charged regions of the drum and is then transferred to paper by roller heating, fusing the carbon-polymer powder to the surface.



Long-lasting
The HERO's pigment inks and photo paper have been treated for optimised ozone, humidity and water resistance. In addition, the printer's inks have been specially designed for print permanence.

LCD
A hi-res, 8.9cm (3.5in) touch display is front-centre-mounted to the 7.1. Through this you can directly tweak print settings and more.

Home
The heart of the 7.1's software is its Home Center. Accessed via the LCD display, this supplies users with photo-editing tools.

Scan
By opening the scanner, users can deposit several photos or documents at once and the built-in software will treat them as individual files.

Computer printer timeline

In both looks and abilities, computer printers have changed drastically since their early days...

1950s | 1960s | 1970s

1959
Xerox 914
The first automatic office copier that can replicate material on plain paper is launched. The unit weighs 294 kilograms (648 pounds), measures over a metre (3.3 feet) in all dimensions and can produce just one copy per 26 seconds.

1977
Xerox 9700
Xerox launches the first commercial xerographic laser printer. The 9700 could operate at two pages per second and had raster font selection and form generation capabilities. It becomes an industry standard.

1980
Epson MX-80
A groundbreaking dot-matrix printer, the MX-80 is the first to combine affordability with print quality in a home setting. Despite its low dot density (60dpi horizontal, 72dpi vertical) it sparks worldwide interest in impact printing.

State-of-the-art printer functionality explained

Discover what makes Kodak's HERO 7.1 printer so versatile

© Kodak

Email
Integration of Kodak Email Print tech enables users to send emails directly to the 7.1's dedicated address and then print them out.

Wi-Fi
The 7.1 is enabled with Wi-Fi (b, g and n standards), which allows for remote and cloud printing from any linked device.

Cloud
A standout feature is the implementation of Google Cloud Print. This enables you to print documents and photos remotely.

Sensor
The HERO is equipped with a paper tray sensor to automatically adjust print settings to the paper type.

Nano
Kodak uses nano-particulate pigment inks throughout the HERO range. This delivers smaller, more uniform particles and, as a result, enhanced image quality.

Trays
There are separate trays for A4 and photo paper (up to 12.7 x 17.8cm/5 x 7in), which avoids the need to constantly swap paper.

Inkjet printers, meanwhile – which today are the most common form of consumer computer printer – were taken up on a mass-market scale back in 1988; the HP DeskJet was the market standard. Inkjets work by propelling ink contained within a cartridge through a print head – commonly also installed in the cartridge – onto a sheet of paper. There are two main types of technology used in modern inkjet printers: continuous (CIJ) and drop-on-demand (DOD). As the names suggest, continuous inkjets deposit ink from a cartridge in a constant stream – albeit broken into droplets at regular intervals, while drop-on-demand inkjets use electrical pulses to pressure-squeeze individual ink droplets out of a print head nozzle onto the paper.

JARGON BUSTER

Perplexing printer lingo is put into plain English in this handy glossary

Dot matrix
A computer printing technique where a print head generates characters by striking an ink-soaked ribbon against paper in a manner reminiscent of a typewriter.

Xerography
A form of dry photocopying in which an electrostatic image is formed on a resinous powder-coated selenium cylinder, before being transferred to a sheet of paper by a process of heating.

Inkjet
A printing technology in which a digital image is created by the propulsion of a multitude of ink droplets onto a sheet of paper.

Toner
A carbon-polymer powder used in laser printers and photocopiers to form printed text and images.

Ribbon
A cloth or plastic strip that is used to hold ink.

Print head
The component that applies a mark or image to a sheet of paper. Print heads come in both fixed and disposable forms, the latter being built in to the cartridge.

Cartridge
A container for an inkjet printer's ink. The receptacle is split into portioned reservoirs (for various colours) and often also contains an electronic chip that communicates with the main device.

Interview Charles Cann

© Kodak

Kodak's marketing director discusses the evolution of the printer

How It Works: First of all, can you talk a little about the development of the desktop printer industry over the last couple of decades?
Charles Cann: When home printers first came out they were mono and then the big deal was colour. After that there was an industry shift towards photos, which was during the mid-Nineties. However, after photo printers became more common, permanence became an issue, with many photos fading quickly over a matter of weeks or months. This was addressed, but then new directions emerged, such as printer connectivity standards, leading to the creation of Wi-Fi-compatible machines.

After then, however, there was a period when there wasn't a big innovative step, though our research at Kodak showed that it was nothing to do with the printer that had stopped people printing, but rather the cost of the consumables. Indeed, when we asked people what dissatisfies you most with your printer, it wasn't anything to do with the noise, the speed or the connectivity options, but the fact that it cost too much. Hence our introduction of our current models, which deliver significantly cheaper running costs.

HIW: The HERO range of printers uses Kodak's new nano-particulate inks. What are these exactly and how are they created?
CC: It is truly amazing technology. In the past the rule of thumb was that a pigment will provide you with more permanence, as it is a physical particle that gets laid down, but less colour gamut. While, in contrast to this, a dye would provide you with better colour but reduced permanence.

However, by grinding these pigment particles down in a polymer milling process to uniform, nanoscale sizes, the light refracts off them differently to traditional pigments, delivering both permanence and a wide colour gamut. Basically, you are getting the best of both worlds.

1984 HP LaserJet

The first desktop laser printer, the LaserJet is introduced for $3,500. Its print cartridge outputs eight pages of text and/or graphics per minute. It's also one of the first printers to be near silent when in operation.

1988 HP DeskJet

The first mass-market inkjet arrives. At $1,000, it is the least expensive non-impact printer on the market. Key to its uptake is its cheap, disposable print head included in each ink cartridge.

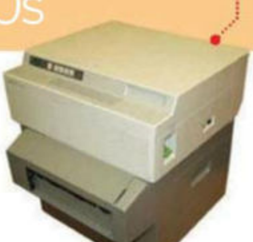
1994 Epson Stylus Color

Epson releases the Stylus Color, the first to bring 720dpi hi-res (for the time) printing to the desktop environment. It has revolutionary Micro Piezo inkjet tech, where piezoelectric actuators are built in to the print nozzles. Below is the 777 model in the series.

2011 Kodak HERO

Kodak launches its HERO range of all-in-one printers. Key to their rapid adoption is both their integration of cloud computing features – such as Google Cloud Print – and also their steep reduction in ink cartridge costs.

1980s



1990s

2000s+

"The PS Vita is primarily a gaming device, but it can also be used for web browsing and phone calls"

Sony's new handheld console

PlayStation Vita

Discover the impressive tech packed into this portable gaming system

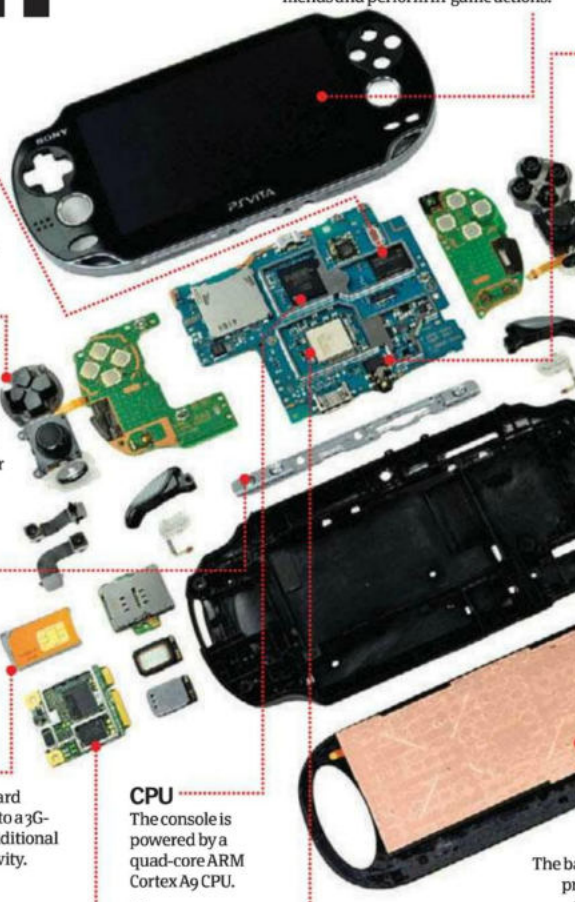
Portable gaming consoles were once vastly inferior to their home console equivalents, but with the arrival of the PlayStation Vita Sony has unleashed a device that rivals the power of the Nintendo Wii and is a worthy on-the-go substitute to the PlayStation 3. Boasting a four-core ARM Cortex A9 CPU as well as a 12.7-centimetre (five-inch) widescreen display, the Vita takes the place of the most powerful portable gaming machine on the market.

The PS Vita is primarily a gaming device, but it can also be used for multimedia purposes, web browsing and Skype calls. Sony has used its own purpose-built operating system on the device that differs from that found on the PlayStation 3, using larger icons and gesture controls to incorporate a responsive touchscreen that is on a par with the most cutting-edge smartphones.

Following on from Sony's previous PlayStation Portable (the PSP), the Vita – for the first time – brings two touch panels and two analogue sticks to a portable gaming console. The lightweight device is similar in design to the original PSP, while the screen is wider than both of those on Nintendo's rival 3DS console. The 12.7-centimetre (five-inch) OLED screen uses capacitive touch technology, as does the pad on the reverse of the console, which allows for further control input. In addition to ten face buttons and two shoulder buttons, the device also boasts motion control in the form of a six-axis gyroscope and accelerometer combination.

While portable gaming was once a low-quality affair compared to home console gaming, there's enough both above and below the bonnet of the PlayStation Vita to warrant its place as the most powerful gaming device in town as it attempts to break preconceptions of how well gaming devices can perform while on the move.

Inside the PS Vita



Front display
The front 12.7cm (5in) screen is a capacitive OLED touchscreen, which can be used to navigate menus and perform in-game actions.

Cameras
Both the front and back VGA cameras can capture 0.3MP shots at 640 x 480px.

RAM
Inside the device is 512MB of regular RAM and 128MB of VRAM.

Battery
The 3.7V 2,210mAh battery supplies up to six hours of charge to the Vita.

Input
There are ten face buttons (four on either side and Start/Select), two shoulder buttons (R and L) and two analogue sticks for control input.

Audio
The Vita has in-built speakers and a microphone to play and record sound.

3G
An external SIM card can be inserted into a 3G-capable Vita for additional network connectivity.

CPU
The console is powered by a quad-core ARM Cortex A9 CPU.

Wireless
The wireless card, with transfer speeds across HSPA+ of up to 14.4Mbps, connects the device to Wi-Fi networks.

Memory
The PS Vita uses a special proprietary SD card from Sony, so regular SD cards won't work with it.

Back panel
The back touch pad is not a screen but provides users with an additional method of multitouch input. For example, it can be used to direct shots during a football game.

The statistics...

PlayStation Vita

CPU: Quad-core ARM Cortex A9

GPU: SGX543MP4+

Dimensions: 182 x 18.6 x 83.5mm (7.2 x 0.7 x 3.3in)

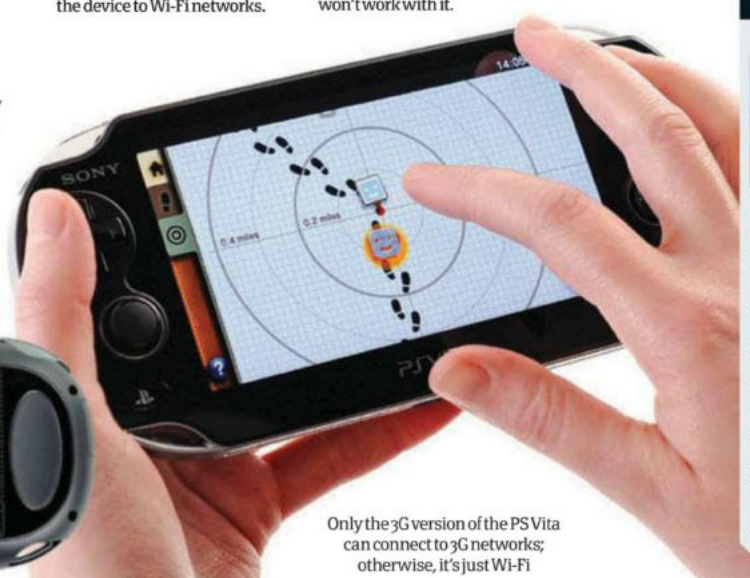
Display: 12.7cm (5in) OLED 16:9 capacitive touchscreen

Resolution: 960 x 544px

Motion control: Gyroscope, accelerometer, electronic compass (all three-axis)

Input: Two analogue sticks, buttons, capacitive touch pad

Connectivity: Wi-Fi, 3G, GPS



Only the 3G version of the PS Vita can connect to 3G networks; otherwise, it's just Wi-Fi

Even the back of the Vita offers an innovative form of touch input

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"The hot dry air is produced by sucking in cold air that then passes through a heating element"

How do condensing tumble dryers work?

What's the quickest way to dry domestic laundry indoors?

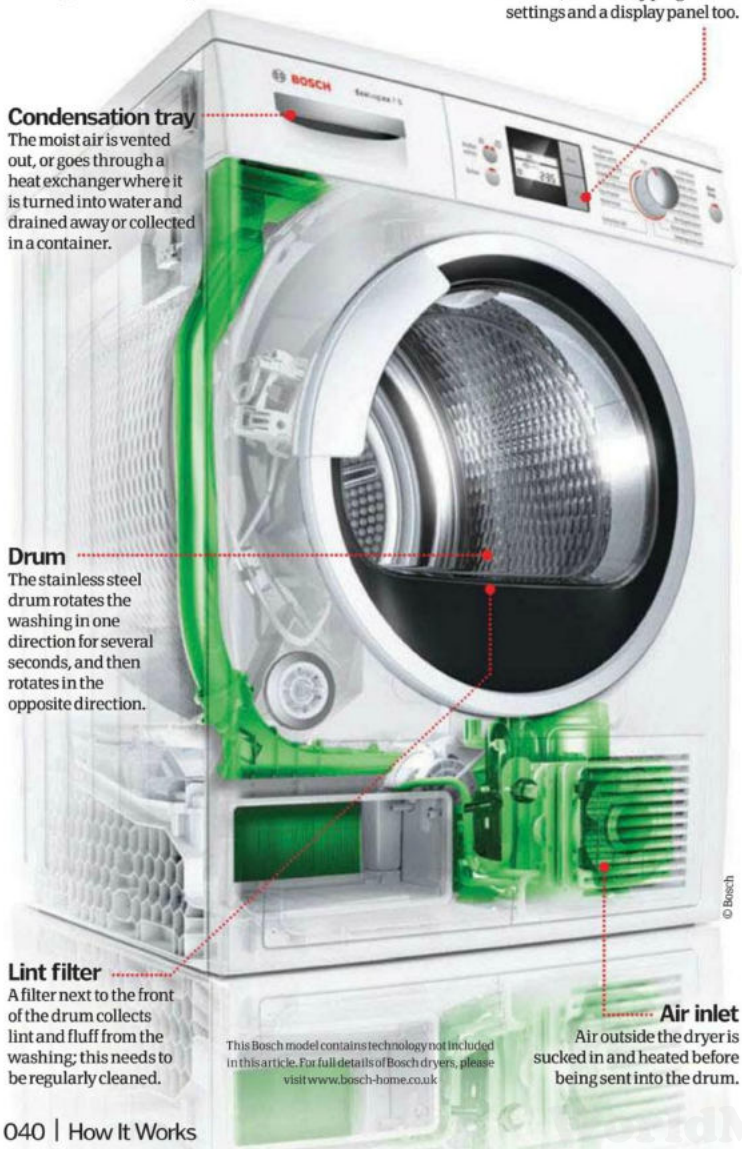
The interior of a clothes dryer consists of a large rotating drum with paddles that lift and separate wet washing as it spins round. This enables the laundry to be efficiently dried by heated air that enters via holes at the back of the drum.

The hot dry air is produced by sucking in cold air that then passes through a heating element. A thermostat sets and regulates the temperature, switching the element on and off to prevent the washing from overheating.

The air exhausted from the drum goes through a filter that traps lint from the dried clothing, and exits through a vent hose. Some tumble dryers send the expelled air through a heat exchanger and condenser to convert it into water that is drained away or collected.

Tumble dryers: the key components

Control panel
Low and high heat settings and a timer are the simplest controls. Some, like this machine, have many programme settings and a display panel too.



Condensation tray
The moist air is vented out, or goes through a heat exchanger where it is turned into water and drained away or collected in a container.

Drum
The stainless steel drum rotates the washing in one direction for several seconds, and then rotates in the opposite direction.

Lint filter
A filter next to the front of the drum collects lint and fluff from the washing; this needs to be regularly cleaned.

Air inlet
Air outside the dryer is sucked in and heated before being sent into the drum.

This Bosch model contains technology not included in this article. For full details of Bosch dryers, please visit www.bosch-home.co.uk

Sound fields
The combination and interaction of the speakers creates the illusion of a 3D audio environment.

Surround-sound headphones

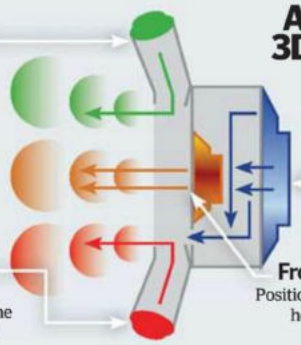
How headphones reproduce three-dimensional audio in your ears

Each earpiece enclosure on a set of surround-sound headphones generally comprises three separate speakers. There is a central speaker that works just like that in normal headphones, and to either side of it are a centre-field speaker and a rear-surround speaker. A central sub-woofer driver, meanwhile, delivers low-frequency bass audio effects.

Such an arrangement corresponds to the commonly used 5.1 surround-sound system that utilises five 3-20,000 Hertz audio channels and a low-frequency 3-120 Hertz effects channel. The six channels individually supply the left and right-field speakers, the left and right surround speakers, the two centre speakers and the sub-woofer.

The differences in the volume and timing of each channel tricks the brain into thinking sound is coming from different directions/sources, which creates a convincing 3D audio landscape for the listener.

Anatomy of 3D surround sound



Centre-field speaker
Angled 90 degrees upwards from the central front-field speaker.

Sub-woofer
This delivers low-frequency bass sound.

Rear-field speaker
Angled 90 degrees downwards from the front-field speaker.

Front-field speaker
Positioned at the centre of the headset enclosure as per standard headphones.

DID YOU KNOW? *Early defibrillation in emergency cardiac arrest situations today can offer a 75 per cent survival rate*

Defibrillators explained

How this machine gets the heart back on track

An automated external defibrillator (AED) sends a burst of electrical energy through the chest wall to the heart. It is used on people suffering from life-threatening fast heart rhythms or when the cardiac muscles are working in an uncoordinated fashion (also known as ventricular fibrillation). The shock briefly stops electrical activity in the heart and, with any luck, enables it to return to a regular rhythm.

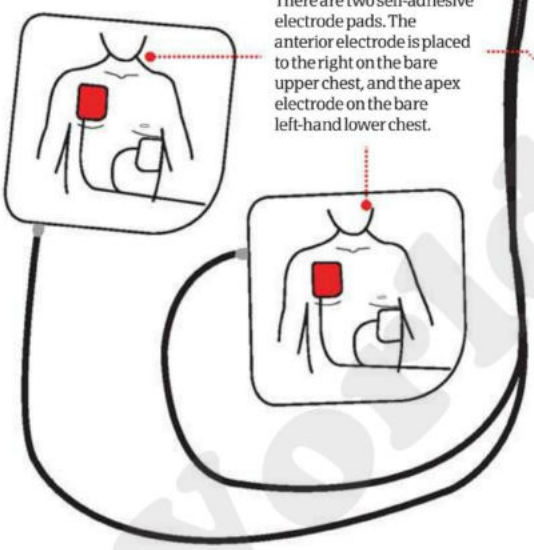
The defibrillator consists of a large capacitor that is charged by a battery. A typical AED has a capacitor that stores a massive 970 joules of energy and delivers 4,200 volts in a matter of milliseconds through the electrodes positioned on the patient's chest.

A microprocessor inside the AED decides whether a shock should be administered based on the ECG (electrocardiogram) reading from the electrodes. In other words, it will not allow someone with a healthy heart rhythm to be shocked.

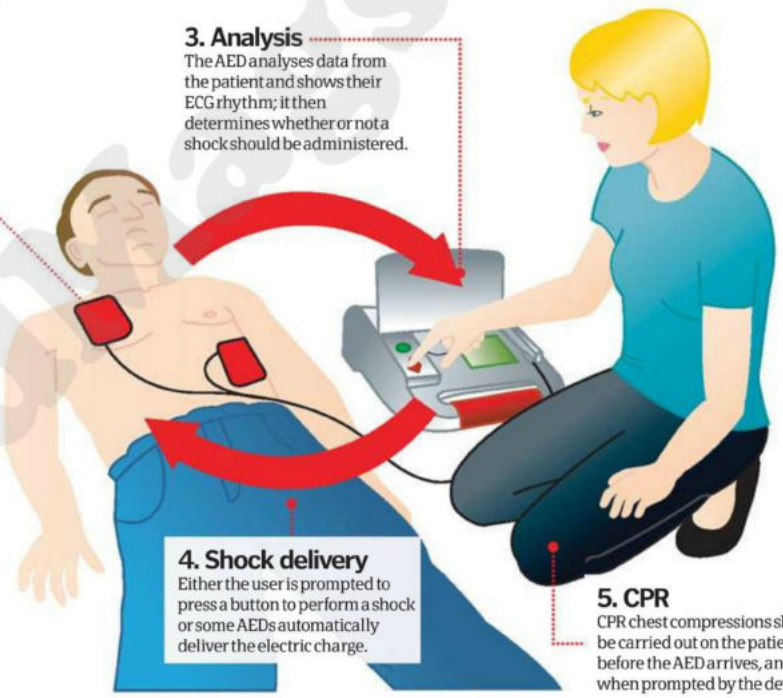
The electrodes should be securely attached to the victim, and they should not be touched during the shocking process. The use of CPR (cardiopulmonary resuscitation) chest compressions is advised before and after the AED is brought into action.

Using an automated external defibrillator

1. Display panel
This shows the operator diagrams illustrating how to assess the patient. This information is supplemented with text and voice prompts that guide the user throughout the process.



2. Electrode pads
There are two self-adhesive electrode pads. The anterior electrode is placed to the right on the bare upper chest, and the apex electrode on the bare left-hand lower chest.



3. Analysis
The AED analyses data from the patient and shows their ECG rhythm; it then determines whether or not a shock should be administered.

4. Shock delivery
Either the user is prompted to press a button to perform a shock or some AEDs automatically deliver the electric charge.

5. CPR
CPR chest compressions should be carried out on the patient before the AED arrives, and when prompted by the device.

"Camera interiors have also advanced with improved sensor technology and increasing megapixel counts"

Next-gen camera technology

Discover the latest advancements in photographic hardware and software

Over the last few years, we have seen some huge developments in digital camera technology. With improved designs and features, manufacturers have enhanced the capture process, ensuring that even a beginner can achieve professional-looking shots regardless of whether they're working with a DSLR or compact camera system.

Raising a few eyebrows along the way, there have been some developments that have stirred up debate – notably in 2008 when HD video was first introduced within a DSLR camera. Met with heavy criticism from the offset, it has only been in the last couple of years with improved performance and acceptance that HD video modes are now considered a standard feature. Equally in 2009, the introduction of 3D technology proved fairly controversial although it has yet to be considered groundbreaking.

Headlining changes, however, have seen camera bodies shrink, while others have been combined. In 2008 the introduction of a completely new camera system – the mirrorless interchangeable lens camera – took the consumer market by storm with product sales now competing with entry-level DSLRs.

Camera interiors have also advanced with improved sensor technology and increasing megapixel counts; indeed, image quality is the best it's ever been. Standard shooting modes have also had revivals with enhanced auto modes now capable of great shots, without you having to understand the theory behind photography.

With all of these exciting advancements in camera tech, photography has become accessible to the masses, making it popular with both young and old generations. We look into some of the latest developments and uncover how they are transforming the field of photography.

DID YOU KNOW?

Extreme geotagging

Most cameraphones will automatically geotag your location when you take a shot. This information is then stored in the image data, which isn't always removed if you upload pictures online. Many celebrity home addresses have been discovered this way via social-networking sites such as Twitter.

DID YOU KNOW? *In a normal camera sensor, green is the most abundant photodiode as the eye is more receptive to this colour*

Multiplying megapixels

For a long time, camera manufacturers were at war when it came to their sensor sizes and megapixel counts. Over the last few years, however, a lot more focus has been placed on improving the image quality, refining the sensors and developing new technology.

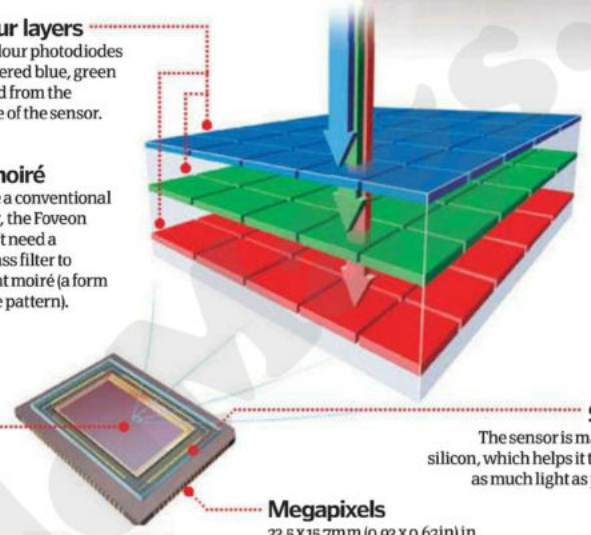
Camera maker Sigma has made considerable inroads into this territory having used some of the latest sensor technology in its new flagship DSLR model, the SD1. Featuring a Foveon X3 direct image sensor, the SD1 offers a staggering 46 effective megapixels, a significant amount for a camera of its type. It is only through comparison with a conventional image sensor that it becomes apparent just how the Foveon X3 packs such a powerful megapixel punch.

Essentially, all image sensors are monochrome and can only detect the intensity of light as opposed to the colour. It is an additional layer of photodiodes that filter the light through to the sensor that make it receptive to colour rays. In a standard colour filter sensor, each pixel is made responsive to one select primary colour of red, green or blue (RGB). The photodiodes are patterned to cover each pixel and are laid out in rows, which alternate between red and green in one row and blue and green in another. As each pixel records only one colour ray of light, a process known as colour interpolation is used to ensure that the final colour image is accurate. What the Foveon sensor does differently is ensure that every pixel can receive and capture full RGB colour using a layering system of photodiodes.

This setup therefore enables the image resolution to be multiplied by three, as effectively each pixel within the Foveon sensor encompasses three pixels to a conventional image sensor's one.

5x © Sigma

Foveon X3 sensor vs a conventional colour filter sensor



Colour layers
The colour photodiodes are layered blue, green and red from the surface of the sensor.

No moiré
Unlike a conventional sensor, the Foveon doesn't need a low-pass filter to prevent moiré (a form of false pattern).

Silicon
The sensor is made from silicon, which helps it to absorb as much light as possible.

Megapixels
23.5 x 15.7mm (0.93 x 0.62in) in size, the APS-C X3 image sensor offers 46 effective megapixels.

Mosaic capture

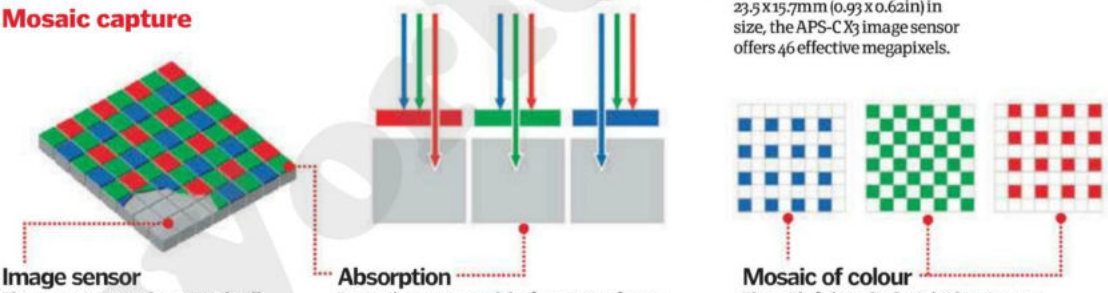
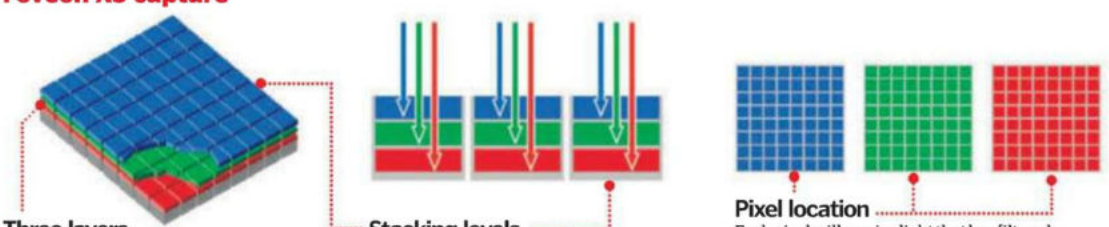


Image sensor
The sensor is monochrome and will only detect the intensity of light as opposed to the colour.

Absorption
Due to the pattern and the frequency of green, only 25 per cent of red and 25 per cent of blue light is recorded compared to 50 per cent of green.

Mosaic of colour
The grid of photodiodes is laid out in rows with green/red then green/blue. Each pixel is then responsive to one colour.

Foveon X3 capture



Three layers
There are three layers of photodiodes on the Foveon X3 that represent each of the primary RGB colours.

Stacking levels
Blue has a shorter wavelength of light so it appears closer to the surface of the sensor than red or green.

Pixel location
Each pixel will receive light that has filtered through all three RGB layers; this will ensure accurate colour reproduction and increase the image size and megapixel number.

Geotagging around the globe

Geotagging is a developing form of technology that has eagerly been introduced into outdoor consumer cameras. Enabling photographers to mark where exactly in the world a photograph was taken, geotagging requires a camera to feature a GPS chip. This GPS receiver can then communicate with a network of orbiting satellites around the Earth to pinpoint the photographer's exact position, using the principle of triangulation. The longitude and latitude co-ordinates are then stored as part of the image's metadata, which you can opt to share online when uploading images to social networks etc.

© Pentax

Tough camera builds

Camera bodies have toughened up considerably thanks to improved build designs and materials. With recent advancements, we've seen cameras emerge that are capable of withstanding almost all of the elements. Offering shockproof, waterproof and freezeproof resistance, manufacturers have ensured you can continue shooting whatever the weather.

Pentax, for example, recently announced its latest outdoor compacts: the WG2 and WG2-GPS. Resembling a transformer, this 16-megapixel compact is capable of shooting underwater down to depths of 12 metres (39 feet), is shockproof from 1.5 metres (4.9 feet) and can withstand freezing conditions up to -10 degrees Celsius (14 degrees Fahrenheit).

Made from a shock-resistant polymer and elastic material, the WG2's unique outer shell is built like protective armour. With angular ridges and corners, its distinct design offers extra grip when shooting handheld and also goes some way to shelter the lens and back screen if dropped. The interior components of the camera are also protected to some degree from falls thanks to an added special shock-resistant cushioning.

Other elements of the outdoors are kept at bay by rubber-sealed buttons on the body and a specialist locking system on the camera's battery and interface covers. The flash and lens, meanwhile, feature protective glass, which has been glued with extra-strong adhesive to ensure the WG2 remains totally watertight even under pressure.

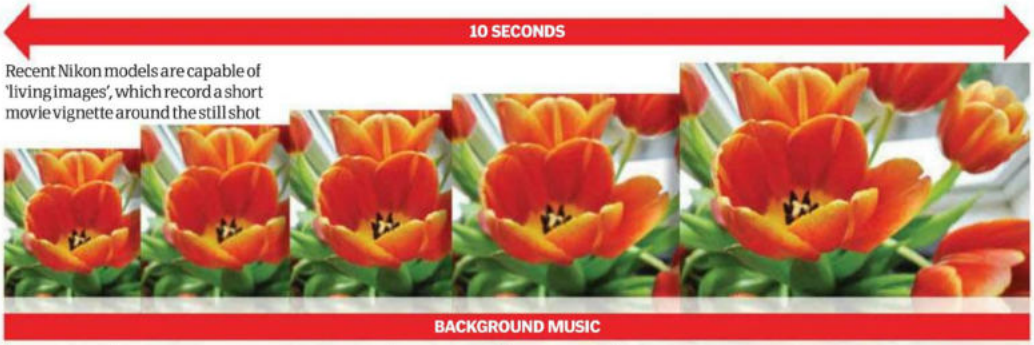
Merging photos and video

© Nikon

Nikon recently announced the release of its first compact system cameras: the Nikon 1 J1 and V1, both of which incorporate some new and exciting shooting modes.

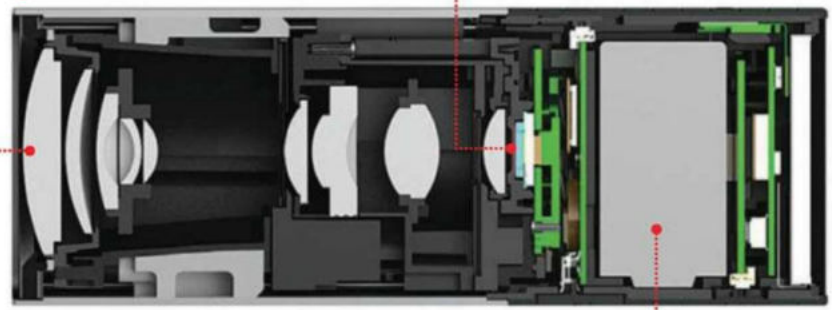
The Motion Snapshot mode appears in both cameras and creates what Nikon describes as a 'living image'. Combining a slow-motion movie file with a still image, this shoot setting enables you to put your photos and video clips together in context. Designed not to slow down the capturing process, the camera will harness its pre- and post-capture technology to record a one-second, 1080p full-HD BGM file while shooting your still. Recording at 60 frames per second, as soon as your finger touches the shutter button, the movie will start capture almost 0.6 seconds before the shutter is fully pressed and continues on for an extra 0.4 seconds once the full-resolution image has been taken. The camera will then process the movie file and slow it down to around 24 frames per second, creating a 2.5-second, slow-motion video clip. Combining both elements together, in playback the camera will sequence the movie footage first before fading into the still. It's an ideal way to share special moments with friends and family online.

Nikon has also developed what's known as the Smart Photo Selector mode. Designed to help ensure you never miss a moment or a great shot, this setting works again with the camera's pre- and post-capture technology. Once this shooting mode has been selected, the Nikon 1 camera will begin photographing 20 full-resolution images at a rate of 30 frames per second, both before and after the shutter button has been released. The camera will then assess each image using a programmed set of good and bad criteria. Factors such as camera blur, composition, smiles, sharpness and blinking will all be taken into account before the camera intelligently selects five final shots for you to choose from including a recommended best.



Recent Nikon models are capable of 'living images', which record a short movie vignette around the still shot

A closer look at the Lytro camera



Light-field sensor
The Lytro's light-field sensor captures 11 million light rays, which are measured as megarays rather than megapixels.

Light and lens
Featuring a fixed f2 aperture and 8x optical zoom lens, users can shoot in most lighting conditions.

Light-field engine
The featured light-field engine 1.0 processes the directional light information from the sensor so that you can adjust the image focus at a later stage using specialist software.

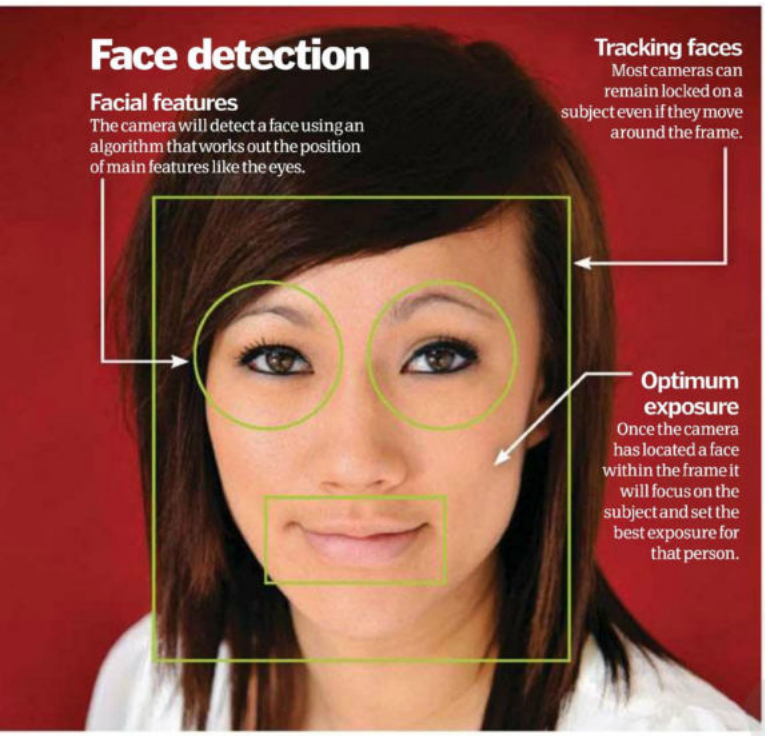
AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

The Nikon 1's Motion Snapshot mode in action

www.howitworksdaily.com

DID YOU KNOW? A more advanced version of face-recall tech has been used to help locate criminals in crowds

Face detection



Face recognition

Face recall
Face recall enables you to save a specific person's face within the camera's memory so that it can locate them for the best exposure in every shot.

Personalised
The Pentax Optio VS20 enables you to save other information such as the subject's name so the camera can alert you when they have been detected within a scene.

© Pentax

"Face detection can now also incorporate smile and blink detection, ensuring you get perfect results every time you shoot"

Face detection and recognition

Face detection isn't entirely new technology but recent developments mean its capabilities are greatly advancing. Enabling a camera to automatically locate a face within the frame, face detection works by using an algorithm that detects and triangulates facial features – usually the eyes and mouth. Once a face has been found, the camera will then optimise its exposure and focus for the subject. Even if the person were to move, provided the facial features remain partially in view, the camera would remain locked and track them. Most cameras provide a multiple setting too so that you can do this for more than one person in a frame, to incorporate group shots of up to ten people.

Face detection can now also incorporate smile and blink detection, ensuring you get perfect results every time you shoot. Programmed into the camera, smile detection simply waits for a change in face shape that resembles a smile before the shutter is released to shoot. Blink detection, on the other hand, will quickly review the results of the last image taken to ascertain whether or not a subject has blinked; the camera will then independently decide whether or not to take another shot.

A more recent advancement to face-detection tech is face recognition. A new feature in many cameras – including Pentax's latest Optio VS20 – face recognition enables you to shoot a portrait and then store that face in the camera's memory. Particularly useful if shooting in a crowd, the camera will automatically locate this person to set the best exposure. It's also been used by authorities to track down criminals and terrorist suspects.

Light-field camera technology

Trailblazing ahead with new camera technology, Lytro announced its first product last year: a light-field camera. Incorporating brand-new tech, the Lytro camera enables you to shoot first and then focus your shots later using your computer.

Unconventional in design and build, the Lytro camera is unique in the way that it captures light. Traditionally a camera will find a focal area depending on how far the subject is in relation to the sensor. The Lytro camera, in contrast, records light at various distances from all different directions so that you can opt to select a focal point later, anywhere in the frame.

Built to incorporate light-field technology, the camera features a set of microlenses in front of its image sensor. The light, which then enters through the front lens, is split through the microlenses and is encouraged to fall across multiple pixel locations at different angles. All of this directional data is then recorded in the camera's light-field engine, which will convey the information to the software on your computer when the images are uploaded for focus adjustment.

Available in an 8GB or 16GB model, this revolutionary point-and-shoot camera means that shots can be recycled again and again, simply by changing the focus.

Controls
The Lytro features just three buttons for power, shutter and lens zoom.

Materials
11cm (4.3in) long, two-thirds of the camera is made from anodised aluminium and the remaining third is rubber.

Touchscreen
Featuring a 128 x 128px touchscreen, users can easily scroll through their shots.

2x© Lytro

Welcome to... TRANSPORT

You better strap yourself in because this issue we are exploring some of the most high-tech military aircraft currently patrolling the skies. Back down on the ground we look at fuel meters, headlights and how high-mobility multipurpose wheeled vehicles, better known as Humvees, are so well adapted to perform in difficult terrains.

52 Fuel gauges

53 RIB vessels

54 Humvees

46 Future fighters
52 Fuel gauges
52 Headlights
53 RIB vessels
54 Humvees

LEARN MORE

F-35 AND THE FUTURE FIGHTERS

Legacy aircraft worldwide are being blown out of the skies by a formation of revolutionary multi-role fighter jets, offering all-round air supremacy and a lethal barrage of explosive new technology

5 TOP FACTS
F-35 LIGHTNING II

Birth
1 The F-35 was born out of the joint strike fighter (JSF) programme, which was initiated to create an aircraft that would replace the F-16, A-10, F/A-18 and AV-8B tactical fighter jets.

X-35
2 The prototype F-35 was the Lockheed Martin X-35, which narrowly beat a rival design from Boeing (X-32), despite both aircraft exceeding or meeting the JSF requirements.

DoD
3 Interestingly, the F-35 designation of the Lightning II is out of sequence with standard DoD numbering. It was supposed to be named the F-24 instead.

Alliance
4 There are eight global partners in the F-35's development along with the USA: the UK, Italy, the Netherlands, Australia, Canada, Denmark, Norway and Turkey.

LiftSystem
5 The STOVL variant of the F-35 Lightning II uses the Rolls-Royce LiftSystem, an innovative propulsion system that allows for the main engine exhaust to be redirected for vertical lift.

DID YOU KNOW? *Total development costs of the F-35 Lightning II are estimated to have run to $40 billion*


State-of-the-art simulation suites have been purposely designed to train F-35 pilots

F-35 Lightning II

Put simply, the most versatile, deadly and technologically advanced fighter jet in the world

"Each F-35 utilises structural nanocomposites, such as carbon nanotube-reinforced epoxy"


An F-35 on Lockheed Martin's primary build line at Fort Worth in Texas

The latest and greatest 'black project' from Lockheed Martin's Skunk Works – technically referred to as the Advanced Development Programs (ADP) unit, a classified division of the company unrestrained by bureaucracy – the F-35 Lightning II is the most advanced fighter jet on Earth. It's the first and only stealthed, supersonic, multi-role fighter.

Born out of a demand to dominate the fluid 21st-century battlefield, replacing a plethora of legacy aircraft such as the F-16 and A-10 Thunderbolt II, the F-35 is rewriting the rulebook on aircraft design, capable of performing almost any possible role imaginable today – be that strike, support or reconnaissance – with greater efficiency than any other aircraft made to date. The cost of this performance? £89m ($139m) per plane.

So what does all that cash actually buy you? To start, the most powerful powerplant ever fitted to a fighter aircraft. The F-35, across all its three variants – read: F-35A, F-35B and F-35C, differentiated largely by takeoff mechanism – is fitted with a Pratt & Whitney F135 afterburning turbofan jet engine, which delivers a mighty 19,500 kilograms (43,000 pounds) of thrust and grants a sound-shattering top speed of over 1,930 kilometres (1,200 miles) per hour; that's over Mach 1.6 or, to put it another way, infinitely faster than your gran's Mini Metro!

The cash, which is being dropped in large quantities by the States, as well as eight global partners including Britain – which is set to deploy the aircraft on its new Queen Elizabeth-class aircraft carriers – also purchases the operator one of the most advanced aircraft structures in existence. Each F-35 utilises structural nanocomposites, such as carbon nanotube-reinforced epoxy and bismaleimide (BMI), to produce a framework unrivalled in lightness and strength, as well as heavily integrating epoxy glass resin to maximise aerodynamics. In terms of skin and coatings, each F-35 sports a radar cross-section (ie radar signature) the size of a golf ball thanks to the heavy implementation of fibre-mat over the fuselage.

The cockpit is also state of the art, delivering a full-panel-width, panoramic glass cockpit display as well as a host of bleeding-edge avionics and sensors such as the Northrop Grumman AN/APG-81 AESA radar and electro-optical targeting system (EOTS). Further, much of the cockpit has been optimised for speech-recognition interaction, allowing the pilot to control many parts of the jet by voice alone.

Of course, the main attraction of the Lightning II is its diverse armaments – the equipment that transforms it from technical marvel into a master of destruction. You want air-to-air prowess? You've got it, with the F-35 capable of launching AIM-120 AMRAAMs, AIM-9X Sidewinders, IRIS-Ts and the futuristic beyond-visual-range MBDA Meteor. For maximum air-to-ground penetration, take your pick from AGM-154 JSOWs, SOM Cruise Missiles and Brimstone anti-tank warheads. Even if you want to engage marine-based targets the F-35 delivers the goods, capable of launching the new anti-ship Joint Strike Missile (JSM). Throw in a raft of other munitions, including the Mark 80 series of free-fall bombs, Mk.20 Rockeye II cluster bomb, the Paveway series of laser-guided bombs and even, in DEFCON 1 situations, the B-61 nuclear bomb and you have one extremely versatile and deadly feat of aviation.

The rate of climb of the F-35 is currently classified

Anatomy of the F-35 Lightning II

How It Works breaks down this awesome piece of military engineering to see what makes it so advanced

LiftSystem

Made by tech-masters Rolls-Royce, the F-35's LiftSystem is an innovative propulsion system that allows for the main engine exhaust to be redirected for direct vertical lift. Perfect for carrier deployment.

Cockpit

A panoramic glass cockpit display (PCD) is standard on the F-35, allowing unparalleled visibility. Speech-recognition systems also offer audio control of parts of the pilot interface.

Sensors

The main sensor installed in the F-35 is an AN/APG-81 AESA radar, which is produced by Northrop Grumman. This main radar is augmented with an electro-optical targeting system (EOTS) mounted under the nose.

Armament

Asides from a stock GAU-22/A quad-barrelled cannon, the F-35 can carry a wide variety of bombs and missiles, ranging from AIM-9X Sidewinders, through AGM-128s and on to JDAM-guided bombs.

History of multi-role fighter jets

The F-35 is the culmination of more than 30 years of development into producing a single, king-of-all-trades fighter plane

1979 Panavia Tornado

The first multi-role fighter to be produced, the Tornado – across its three variants (each providing differing abilities) – offered its owner the best of striker, bomber, interceptor and reconnaissance aircraft.

1983 McDonnell Douglas F/A-18 Hornet

Maybe the most recognisable multi-role fighter until the F-22, the Hornet was an all-weather, carrier-capable fighter specialising in short/medium-range bombing ops.

1988 JAS-39 Gripen

Another early delta-wing, multi-role fighter, the Gripen was designed to be incredibly lightweight for a fighter and sported impressive air-to-ground bombing capabilities. It has recently been upgraded for continued use.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

An F-35 in action on the *Future Weapons* show

www.howitworksdaily.com

DID YOU KNOW? *The F-35 has the capability to carry and launch a B-61 nuclear bomb*

Structure

The F-35 is the first mass-produced aircraft to include structural nanocomposites, primarily utilising carbon nanotube-reinforced epoxy. Other materials include bismaleimide (BMI) and composite epoxy glass resin.

Powerplant

A Pratt & Whitney F135 afterburning turbofan delivers 19,500kg (43,000lb) of thrust to the F-35, allowing a top speed of over 1,930km/h (1,200mph). The engine is the most powerful ever installed in a fighter aircraft.

Wings

The total wing area of the Lightning II varies dependent on configuration, with the CTOL and STOVL variants sporting 43m² (460ft²) and the CV variant 62m² (668ft²).

© Alex Pang

Stealth

The F-35 has a tiny radar cross-section (the size of a golf ball) thanks to heavy implementation of fibre-mat in its construction, as well as stealth-friendly chines for vortex lift as used on the SR-71 Blackbird.

"The F-35's LiftSystem allows for the main engine exhaust to be redirected for direct vertical lift"

The statistics...

F-35A

Crew: 1

Length: 15.7m (51.4ft)

Wingspan: 10.7m (35ft)

Height: 4.3m (14.2ft)

Weight: 13,300kg (29,300lb)

Powerplant: 1 x Pratt & Whitney F135 afterburning turbofan

Dry thrust: 125kN (28,000lbf)

Thrust with afterburner: 191kN (43,000lbf)

Max speed: Mach 1.6 (1,930km/h; 1,200mph)

Max range: 2,220km (1,379mi)

Max altitude: 18,288m (60,000ft)

Thrust/weight: 0.87

g-limit: +9 g

Guns: 1 x General Dynamics GAU-22/A Equalizer 25mm four-barrelled Gatling cannon

Hardpoints: 6 x external pylons, 4 x internal pylons

Max payload: 8,100kg (18,000lb)

Armament: Air-to-air, air-to-ground, anti-ship

© MOD Czech Republic

1996 Sukhoi Su-30

© Sergey Krivchikov

Envisioned as a fighter jet with excellent air-to-surface deep interdiction prowess (the ability to strike hostile targets at extreme range from friendly forces), the Russian Su-30 typifies multi-role designs from the mid-Nineties.

2000 Dassault Rafale

Marketed by Dassault as an 'omnirole' jet, the Rafale was an agile delta-wing fighter, specialising in air supremacy. A collapse in a multi-nation agreement, however, led it to be used for other roles by France and India.

2005 Lockheed Martin F-22 Raptor

Originally conceived as an air superiority fighter, the F-22 evolved over time into a multi-role jet, capable of ground attack and electronic warfare roles thanks to its extremely low radar cross-section.

© Rob Shenk

> "This engine's thrust allows the T-50 to continuously fly at supersonic speeds without the afterburner"

According to government officials, the T-50 will have a low radar cross-section and have the ability to supercruise (perform sustained supersonic flight)


As well as air-to-air roles, the Typhoon can adapt to air-to-ground operations, delivering GBU-16 Paveway II bombs

Sukhoi T-50

Russia's hottest jet project currently in development, the highly classified Sukhoi T-50 is a fifth-generation multi-role fighter designed to deliver awesome long-range strike capabilities

Arguably the main competitor to the F-35 Lightning II, the Russian-made Sukhoi T-50 is an extremely advanced, twin-engine, multi-role jet fighter that, aside from being a top-level black project (in other words, highly hush-hush), promises to deliver an insane top speed, range and payload.

Power, which is titanic – 267 kilonewtons (66,000 pounds-force) of thrust on afterburner – comes courtesy of two Saturn 117 turbofan jet engines. The thrust has been drastically increased since the previous AL-31 powerplant and this not only allows the T-50 to easily surpass Mach 2 (a top speed of 2,500 kilometres, or 1,500 miles, per hour) but also supercruise – continuously fly at supersonic speeds without engaging the afterburner.

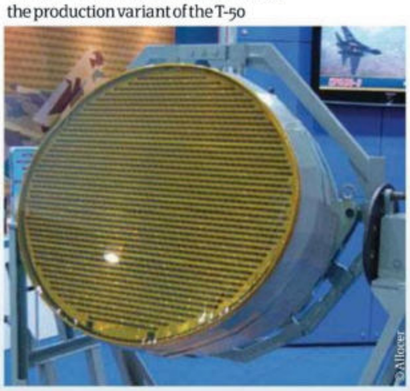
The reason for the twin-engine setup, as well as the supersized fuel tanks, is to help fulfil the T-50's design focus to specialise in long-range interdiction operations (striking at enemy targets that are located at a great range from allied forces). This is a core competency for modern Russian military bombing aircraft due to the size of the country and the great distances between stopover points.

Avionics are handled by an integrated radar complex, which includes three X-band active electronically scanned array (AESA) radars mounted to the front and sides of the aircraft, an infra-red search and track (IRST) system, as well as a pair of L-band radars on the wing leading edges, which are specially designed to detect very low observable (VLO) targets.

In terms of firepower, the production variant of the T-50 will boast up to two 30-millimetre cannons, as well as a mix of Izdeliye 810 extended-beyond-visual-range missiles, long-range missiles, K74 and K30 air-to-air short-range missiles and two air-to-ground missiles per weapons bay. Free-fall bombs can also be carried – with a limit of up to 1,500 kilograms (3,300 pounds) per bomb bay – as well as various anti-AWACS (airborne warning and control system) armaments, such as the RVV-BD variant of the Vympel R-37.

Currently only a handful of T-50s have been produced and flown, however it is expected that throughout its 35-year life span beginning in 2016, more than 1,000 jets will be made, each unit costing between £31-36m ($48-57m).

The NIIP AESA radar as will be used on the production variant of the T-50



The statistics…

Sukhoi T-50

Crew: 1
Length: 19.8m (65.9ft)
Wingspan: 14m (46.6ft)
Height: 6.05m (19.8ft)
Weight: 18,500kg (40,785lb)
Powerplant: 2 x AL-41F1 afterburning turbofans
Max speed: Mach 2+ (2,500km/h; 1,560mph)
Max range: 5,500km (3,417mi)
Max altitude: 20,000m (65,600ft)
Rate of climb: Classified
Thrust/weight: 1.19
g-limit: Classified
Guns: 2 x 30mm cannons
Hardpoints: 6 x external pylons, 4 x internal pylons
Armament: Air-to-air, air-to-ground, anti-ship

1. ELECTRIC

Electronic warfare

Some jets use specialised equipment to control, disrupt or attack enemy targets with a host of cutting-edge electromagnetic weaponry.

2. CLOSE CALL

Close air support

Supporting ground troops with air action despite their close proximity. Achieved with fixed-wing or rotary aircraft.

3. LONG DISTANCE

Air interdiction

This role involves using aircraft to attack tactical ground targets that are not currently in close proximity to ground forces but located at a considerable range.

DID YOU KNOW? *The Sukhoi T-50 is expected to be renamed to the Sukhoi PAK FA when it is officially launched in 2016*

A Typhoon undertakes a low pass at high speed

© BAE Systems

Eurofighter Typhoon

The Typhoon is one of the most adaptable multi-role fighters in operation today and has recently been upgraded to deliver enhanced air superiority and all-round lethality in its combat operations over the next decade

The Eurofighter Typhoon is currently one of the most agile aircraft in the world. It is so agile, in fact, that attempting to blow it out the skies is like trying to make a mile-long sniper shot in high wind. Why? It was built to be fundamentally aerodynamically unstable and, if it were not for its advanced fly-by-wire control system generating artificial stability, would be too much for even the most experienced pilot to handle. This instability, however, allows for pilots to perform some physics-bending manoeuvres at just plain stupid speeds – read: upwards of Mach 2 – delivering them a combative edge and helping to ensure total air supremacy.

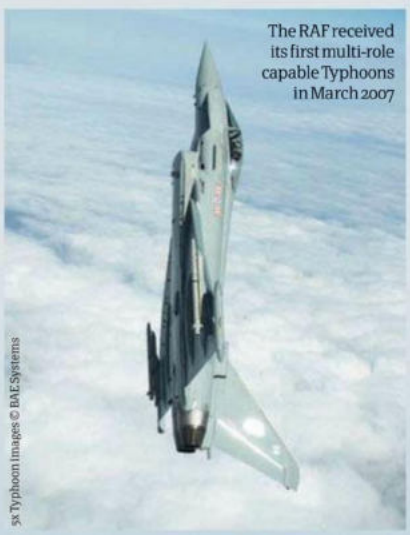
Of course, agility alone can only take you so far – especially so when the hardware needs to fulfil almost every airborne military role imaginable. Good job then that the Typhoon can carry an abundance of weapons. You need to go toe-to-toe with enemy fighters in an air-to-air combat dogfight? No problem, take your pick from Sidewinder, ASRAAM and AMRAAM air-to-air missiles. Need to undertake a bombing run through hostile territory? Well, the Typhoon's 13 hardpoints allow for Maverick, HARM and Taurus munitions to be smartly delivered (via laser-guiding and GPS) with ice-cold efficiency. Need to disrupt a hostile target's comms network through a tactical electronic warfare strike... You get the point.

Supporting this awesome arsenal is an upgraded weapons system, which has been designed to unite the pilot and hardware like never before. Typhoon pilots are now linked to their aircraft by an 'electronic umbilical cord', which extends from a comms-optimised helmet directly into the jet's system. This not only allows images and videos of notable contextual information to be directly fed to the helmet's visor for immediate consultation by the pilot, but also enables special nodules on the helmet to be tracked by fixed sensors in the aircraft's cockpit. As such, wherever the pilot's head moves, the aeroplane knows exactly where they are looking and can automatically prep weapon stores dependent on the perceived level of threat.

Any future fighter though also needs to be prepared to defend itself against a barrage of smart munitions, which again – thanks to the Typhoon's perpetual evolution – the hardware delivers in spades. The entire jet is protected by a high-integrated defensive aids sub-system (DASS), also nicknamed Praetorian. Praetorian consists of a wide array of sensors and electronic/mechanical systems – detection is handled by both a radar warning receiver and laser warning receiver – that automatically track and then respond to both air-to-air and surface-to-air threats. The plane can respond by releasing chaff (eg small bits of aluminium or metallised glass, etc), flares and electronic countermeasures (ECM), as well as by releasing a towed radar decoy (TRD).

As of October 2011, 300 Typhoons are recorded to be in operation worldwide with over 170 aircraft on order.

> *"The Typhoon's 13 hardpoints allow multiple munitions to be smartly delivered with ice-cold efficiency"*



The RAF received its first multi-role capable Typhoons in March 2007

© BAE Systems

The statistics...

Eurofighter Typhoon

Crew: 1

Length: 16m (52.4ft)

Wingspan: 11m (35.9ft)

Height: 5.3m (17.3ft)

Weight: 11,150kg (24,600lb)

Powerplant: 2 x Eurojet EJ200 afterburning turbofans

Dry thrust: 60kN (13,000lbf) each

Thrust with afterburner: 89kN (20,000lbf) each

Fuel capacity: 4,500kg (9,900lb) internal

Max speed: Mach 2+ (2,495km/h; 1,550mph)

Max range: 3,790km (2,350mi)

Max altitude: 19,810m (64,990ft)

Rate of climb: >315m/s (62,000ft/min)

Thrust/weight: 1.15

g-limit: +9/-3 g

Guns: 1 x 27mm Mauser BK-27 revolver cannon

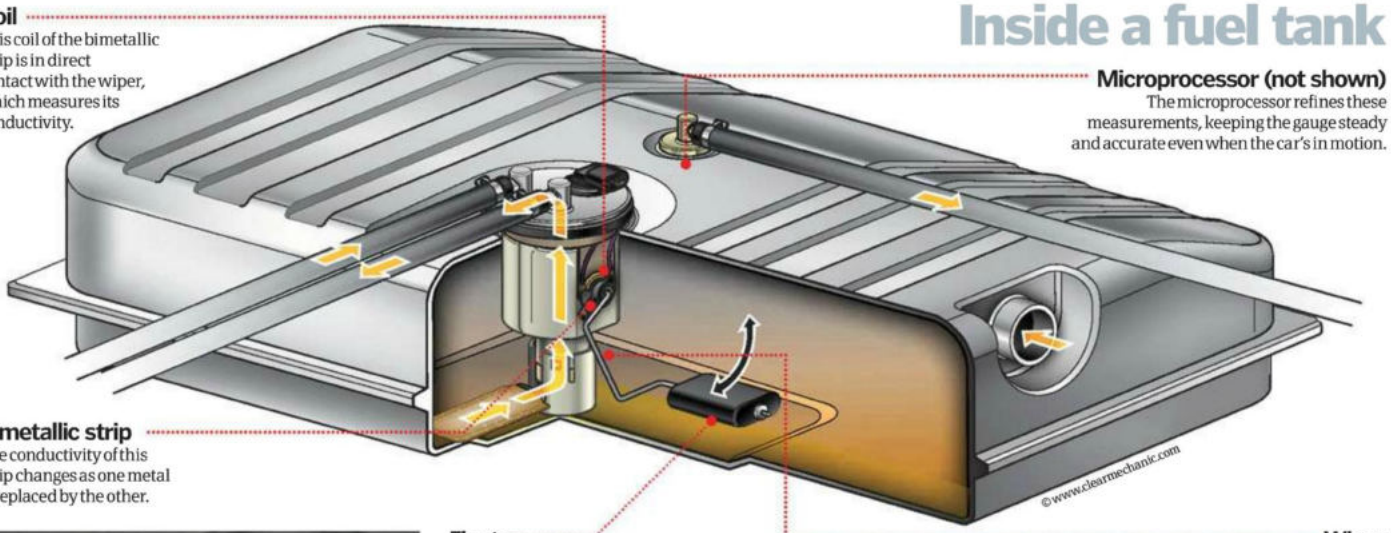
Hardpoints: 13 (8 x under-wing, 5 x under-fuselage)

Max payload: 7,500kg (16,500lb)

Armament: Air-to-air, air-to-ground, anti-ship

"...the glass in the headlight casing is reticulated to act as a prism"

Inside a fuel tank



How your fuel gauge works

No one wants to be running on empty, making this fuel monitor a vital part of every automobile

Fuel gauges operate on electrical resistance, using a float with an attached metallic rod as the internal 'needle'. A wiper conducts electrical current from the rod to the gauge and the more of the rod that's exposed, the less conductive it becomes, which in turn reduces the fuel gauge level. This older system is effective but works on a relative scale; you're never sure just how close to empty the tank is.

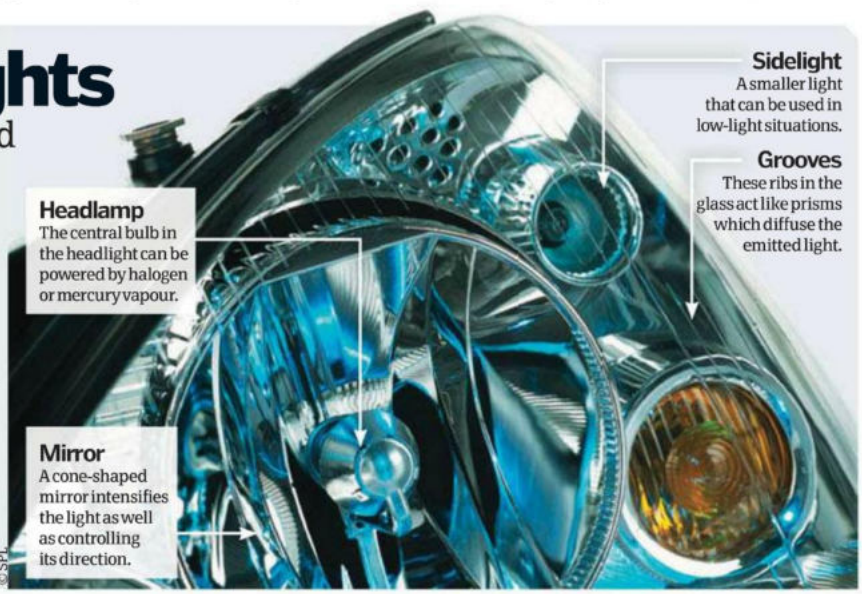
Modern fuel gauges work off the same principle but add a microprocessor to read the resistance in the tank. They can also compensate for the shape of the tank, calculating the volume of fuel remaining far more accurately. Even better, the microprocessor can 'dampen' needle movement, meaning that your fuel gauge doesn't swing wildly as you turn corners or climb hills, which sloshes the fuel in the tank, along with the float, exposing more of the rod.

Modern headlights

How cars illuminate the road ahead

In many ways, the key to a headlight lies not in the light itself, but in what lies in front and behind it. The parabolic mirror positioned behind the headlight's bulb is designed to concentrate and redirect the light back out the front of the device. At the front of the headlight, meanwhile, the glass in the casing is reticulated to act as a prism, diffusing the light and projecting it across a much wider area. This is further aided in modern cars by high-intensity discharge (HID) bulbs. These use mercury vapour instead of the traditional halogen bulbs to burn both brighter and faster.

The driver can also 'dip' their headlights to prevent obscuring oncoming drivers' vision, or to avoid the glare from fog. This is done by slightly altering the angle of the mirror behind the headlamp, projecting the same intensity of illumination but at a lower angle directed at the road.



KEY DATES
LEAD-UP TO RIBS

1838 — Charles Goodyear discovers the process to vulcanise rubber, which could be used as a fabric.

1839 — The Duke of Wellington tests the first inflatable boat, making a primitive pontoon out of vulcanised rubber.

1866 — For the first time, four men cross the Atlantic in an inflatable three-tube raft; it is called Nonpareil.

1907 — The outboard motor is invented by Ole Evinrude, but it isn't used on inflatable boats until the Fifties.

1969 — Desmond Hoare patents the idea for a rigid-hulled inflatable boat following research at Atlantic College, Wales.

DID YOU KNOW? *The fastest circumnavigation of Britain in a RIB took 31 hours, 22 minutes and 46 seconds in 2005*

RIB boats

Discover how these versatile vessels combine a rigid frame with inflatable support to ensure they almost never sink

The rigid-hulled inflatable boat (RHIB), or rigid inflatable boat (RIB) for short, was first built in the Sixties, and has since proved highly versatile. The boats are characterised by their inflatable sections that sit atop a rigid hull, making them sturdy but also manoeuvrable. They are useful patrol and rescue boats, and ideal for ferrying passengers between vessels or to and from shore.

Most RIBs are between four and nine metres (13 and 28 feet) in length, and are driven by either one or more outboard motors or a single inboard motor. The power of these boats can range from a tame four kilowatts (five horsepower) up to 220 kilowatts (295 horsepower). The hulls of RIBs are designed to hydroplane so that they glide across water, even in rough conditions.

The hulls are commonly made from steel, aluminium, wood or a combination of wood and glass-reinforced plastic (GRP, or fibreglass), while Kevlar is occasionally used for extra strength. The inflatable collar of a RIB consists of separate sections so that, in the event of a puncture, the vessel can still stay afloat. The tough material used is commonly Hypalon or PVC (polyvinyl chloride).

There are also larger RIBs that have hard tops (cabins) for extra protection from the elements for both the crew and equipment.

"Serving over 40 nations, around 200,000 Humvees have been built"


A jack of all trades, the Humvee can be configured to perform many roles


A snorkel and raised exhaust make the Humvee a great amphibious vehicle

The Humvee

The high-mobility multipurpose wheeled vehicle (HMMWV) roars off the production line ready for action

Designed to replace several outdated American military vehicles, the high-mobility multipurpose wheeled vehicle, or Humvee, has been in production since 1985. Originally intended as a light utility vehicle, there have been more than 20 variants of this highly customisable, modular platform. Serving over 40 nations, around 200,000 Humvees have been built to date. Able to carry and deploy almost anything, from fully armed troops to anti-aircraft missiles, the Humvee is an open-topped scout vehicle, an armoured personnel carrier, ambulance, a TOW missile launcher, a communication centre, a heavy machine gun platform and whatever else the situation requires.

The latest models are unrivalled in their off-road capability, and are based around a 6.5-litre (1.7-gallon) V8 Turbo diesel engine which produces 142 kilowatts (190 brake horsepower) and 515 Newtons per metre (380 pounds force per foot) of torque. This power is sent to all four wheels through an electronically controlled four-speed automatic gearbox, using a series of differentials. The drivetrain is rather unconventional as the wheels themselves contain portal-geared hubs, which not only double the torque generated, but due to the offset driveshaft inputs, enable the vehicle's ground clearance to be significantly higher than a regular centre axle would allow. This innovative drivetrain, coupled with independent suspension and 94-centimetre (37-inch) tyres, allow the Humvee to travel at 113 kilometres (70 miles) per hour or to climb slopes of 60 per cent – though some Humvees have been seen to climb near-vertical walls! The internal environment is fully air conditioned, while a deep-water fording kit allows the vehicle to cross rivers almost completely submerged. These capabilities, combined with design features such as the sturdy chassis, corrosion resistance plus high commonality and interchangeable parts, enable the Humvee to be flexible, dependable and rugged even in the harshest of environments.


The turret can be fitted with weapons for all kinds of combat situation

Armour options

Since the Humvee was introduced, soldiers have demanded increasingly more protection from it. Early versions had fabric doors and no roof, but the demands of Somalia, Iraq and Afghanistan demonstrated the need for improved armour. Many improvised solutions have been tried in the field in recent years, including sandbags and welding scrap metal to the chassis. However, heavily armoured versions are now available from the factory, as are retrofit kits, which include under-body plates, heavy doors, armoured seats, weapon shields and many other additions. The latest iterations offer the crew protection from assault rifle bullets, some air-burst artillery, and up to 5.4 kilograms (12 pounds) of explosives, thanks to thick steel armour, energy-absorbing coatings and mounting, and reinforced glass. All of this comes at a price, though, with many Humvees carrying 907-1,814 kilograms (2,000-4,000 pounds) of armour, which can only be taken in place of cargo and equipment. Work is underway to make the Humvee more resistant to buried explosives, as the large flat floor is not effective against these.

1. MEAN

Willys Jeep
Released at the end of WWII in 1945, the civilian version of the military vehicle was updated regularly and is still on sale to this day.

2. MEANER

Land Rover Defender
Still used by the British armed forces today, the Land Rover Defender is based on the original 1948 Land Rover.

3. MEANEST

Hummer H1
Also built in the HMMWV factory, the main difference between this beast of a civilian truck and the military version is the colour.

DID YOU KNOW? *Arnold Schwarzenegger was so impressed with the Humvee, he insisted AM General sold him one*

© AM General

Inside the Humvee

We tear down one of these tough vehicles to find out what makes it so well suited to off-road combat

Weapon turret
A huge selection of weapons can be fired from the turret position.

Snorkle
The snorkel here (and raised exhaust, see far right) allow the vehicle to submerge in water up to 1.5m (4.9ft).

Climate control
Air conditioning is a welcome feature when operating in hot countries.

Hard target
Armour configurations vary from having doors that weigh more than a heavyweight boxer to having no doors at all.

Lightweight
Riveted and bonded aluminium body panels give good strength, low weight and flexibility to help off-road performance.

© Alex Pang

Rugged chassis
All Humvees share common components to help serviceability, including the chassis frame.

4x4
Three differentials ensure power goes to the wheels at all times, giving great traction.

Diesel power
The massive V8 diesel engine produces lots of torque to give excellent rough terrain capability.

Portal hubs
The large wheels contain the portal gearing, and the tyre pressures can be altered remotely from the driver's seat.

Protection
The important mechanical parts are protected high up within the vehicle, including the drivetrain and disc brakes.

Packing a punch

There was always a requirement to arm the Humvee to provide fire support and self-defence, but the variety of weapons it can carry is astonishing. Starting with a choice of general-purpose machine guns, most weapons can be fired manually or fitted to the remotely operated CROWS turret system. The most common weapon choice is the legendary M2 Browning .50 Calibre. However, should there be a need to raze everything in sight to the ground, the gunner can unleash 100 shots per second using the awesome M134 minigun. For even bigger bangs, the 40-millimetre (1.6-inch) grenade machine gun can launch 60 high-explosive grenades per minute. Should an enemy bring a tank to the fight, the Humvee can launch the TOW anti-armour missile from 3.8 kilometres (2.3 miles) away, or in situations requiring a little bit of overkill, the Humvee is designed to tow a Howitzer cannon. The ultimate version, however, has to be the Boeing-developed Avenger, which carries up to eight stinger anti-aircraft missiles, with proposals for additional weapons including a one-kilowatt laser.

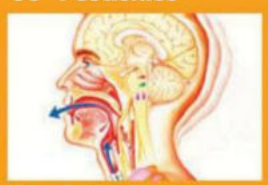
For long-distance enemies more heavy-duty weapons can be deployed

Welcome to...
SCIENCE

This month we take an in-depth look at human biology with a trio of features. Discover how the retina enables us to see, how proteins are made to help us grow and heal, plus how sneezing works. On top of all this, with the Olympics on its way to the UK, we get physical with some of the best-loved sporting events.

59 Making protein

60 Pesticides



61 Sneezing

56 Retina
59 Protein production
60 Pesticides
60 Centre of gravity
61 Sneezing
62 Olympic events

LEARN MORE

The retina

How does this photosensitive layer enable us to see pictures?

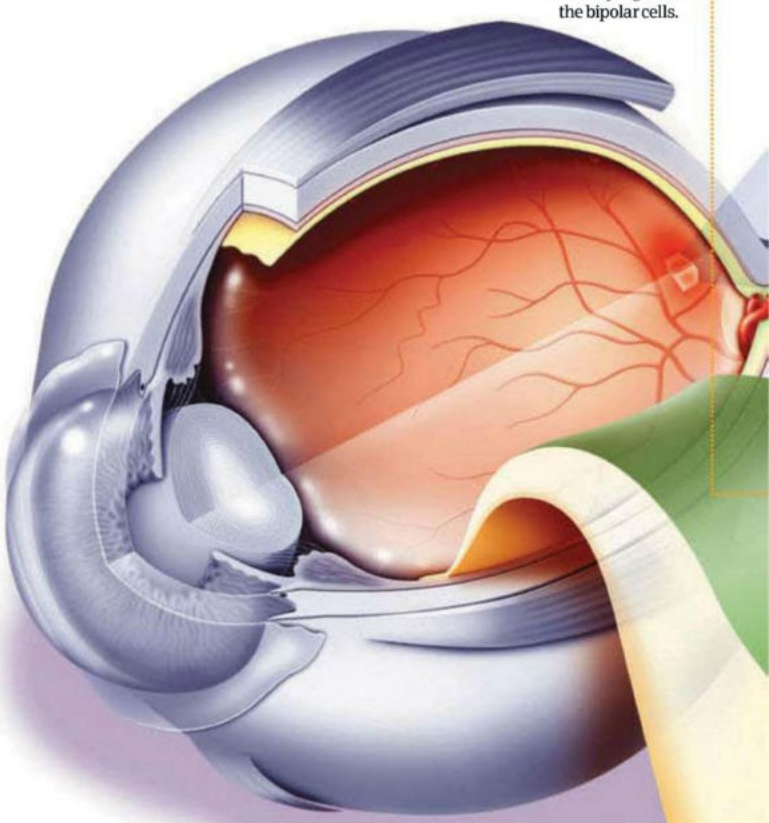
The retina is a special type of light-sensitive tissue located in the interior of the eye that's so analogous to brain tissue, it's considered a part of the central nervous system. If you consider our eyes to be cameras, then the retina is the film. However, the retina does much more than just send a 'picture' to the brain – it actually has to compress the image so that it can be conveyed via the optic nerve, because the photoreceptors in the retina can take in more information than the optic nerve can convey.

Although it looks like a single layer, the retina is actually very complex and comprises ten layers of nerve cells, all of which are connected by synapses. Within each of these layers are several different types of cells: the photoreceptors called rods and cones, photosensitive ganglion cells, bipolar cells and other cells that assist with regulating light input as well as processing and transmitting images. Rods and cones each have their own function. Rods are more sensitive to light and are responsible for night vision and peripheral vision; each one can respond to a single photon, or particle, of light. Cones, on the other hand, work in bright light and are responsible for seeing colour, fine detail and rapid movements.

Until the Nineties, it was thought that only rods and cones were involved in sight. Then researchers discovered a much rarer type of cell called photosensitive ganglion cells. These cells help regulate pupil size and the light/dark cycle, or circadian rhythms, that we function by.

Light reaches the rods and cones by first passing through transparent layers of nerve cells. When it reaches these photoreceptors, the light causes chemical changes in the rods and cones. The raw data is sent back through the layers of nerve cells, which process and encode the image before sending it via the optic nerve to the brain.

Amacrine cells
These are responsible for 70 per cent of the photoreceptors' input and they regulate the bipolar cells.



Retina anatomy

The eye is one of the most complex structures in the body – and the retina plays a vital role...

Blind spot

We all have a blind spot, or scotoma – a place on the retina where there are no photoreceptive cells to perceive light. Known as the optic disc, this area is where the optic nerve passes through the retina on the way to the brain. Although the blind spot is sizeable, we don't notice it. That's because the blind spot in each eye is in a different place, so the other eye 'fills in' the blanks. To the right we have included a 'blind spot test'. When you close your left eye and focus on the circle, then slowly get closer to the page, the plus sign will vanish!

THE BLIND SPOT TEST

5 TOP FACTS
VISION

TV and computer use
1 Despite popular belief, watching TV too closely isn't bad for your eyes. Neither is staring at a computer, although it can make your eyes dry because you blink less often.

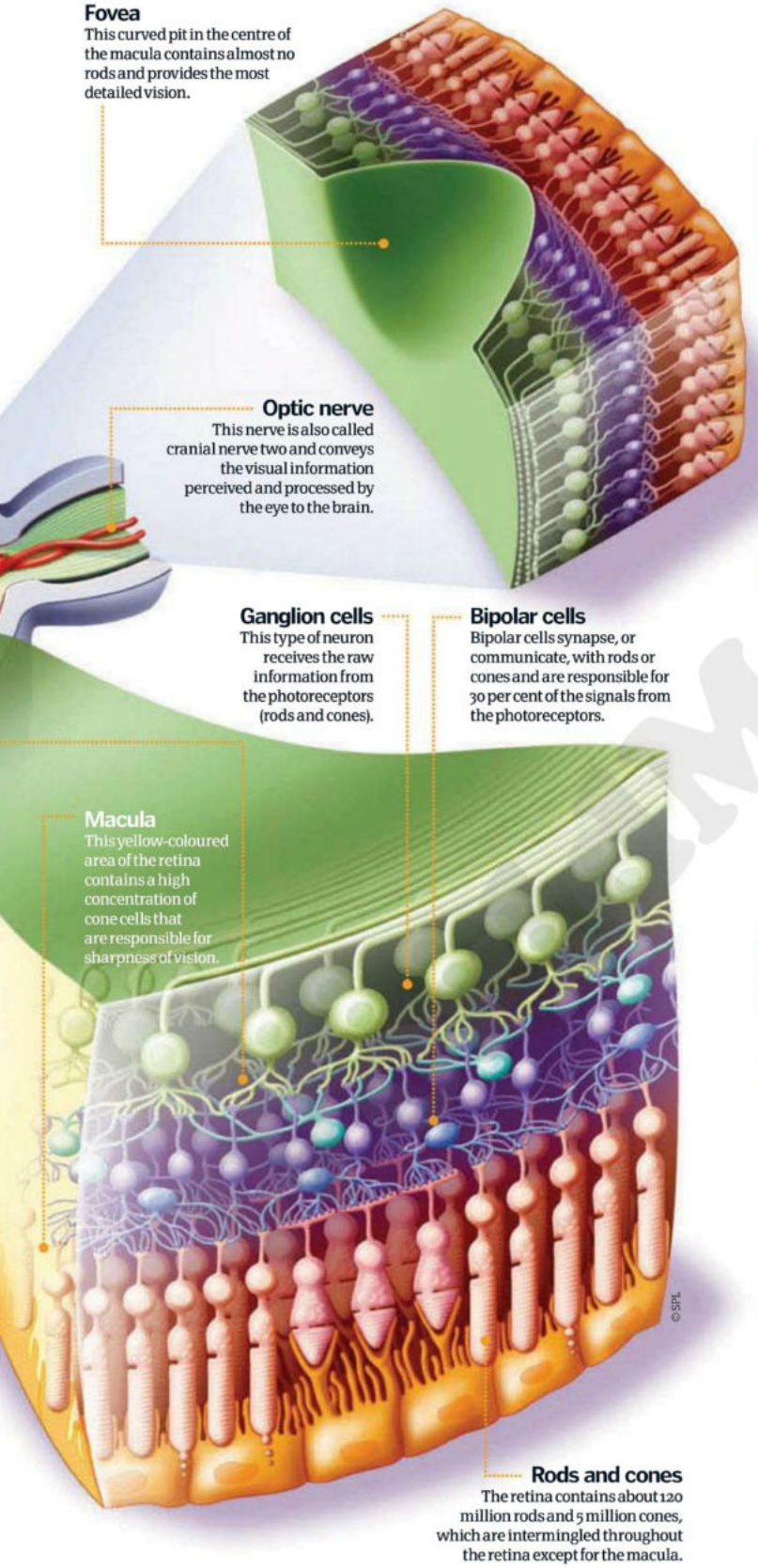
Speedy sight
2 A 2006 study conducted at Georgetown University in Washington DC calculated that the human retina has a bandwidth of about 8.75 megabits per second.

Donor retinas
3 While corneas are often transplanted, attempts at retinal transplants have not succeeded so far. Researchers are currently working on making an artificial retina.

The filmmaker's eye
4 One-eyed Canadian filmmaker Rob Spence announced he had commissioned a prosthetic eye consisting of a camera and transmitter that would digitally record everything he sees.

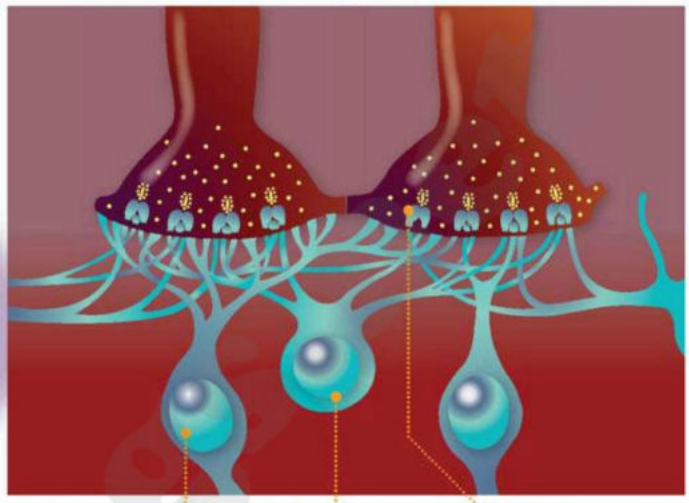
Seeing red
5 Red-eye when you take pictures is caused by the light from the flash bouncing off the capillaries in people's eyes. To prevent it, ask them not to look directly at the camera.

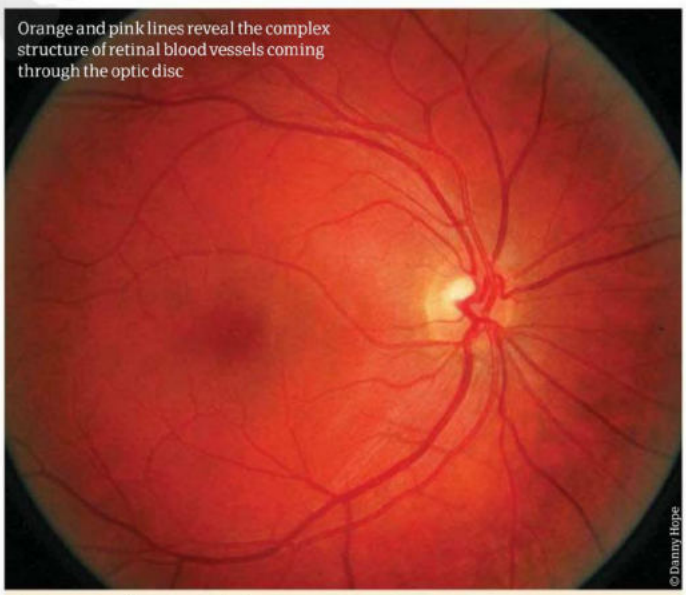
DID YOU KNOW? *Octopus eyes have nerves attached to the rear of the retina, meaning they don't have a blind spot like humans*



Synapses

Neurons work together to combine data from rod and cone cells into messages that travel to the brain




Orange and pink lines reveal the complex structure of retinal blood vessels coming through the optic disc

© Danny Hope

Retinal scan

Iris scanning is the more common form of biometrics when it comes to eyes, but did you know that our retinas also have special identifying characteristics? It all comes down to the complex network of blood vessels in the retina; even twins' retinas are different. When you look into a retinal scanner, a low-energy beam of infrared light is reflected by the capillaries. The resulting unique pattern is then stored as code within a database. Retinal scanners are fast and reliable, but the downside is that the scanners are expensive and the pattern can change over time with certain diseases or other eye problems.

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5 TOP FACTS
PROTEIN

Pokémon
1 Speedy Pokémon character Pikachu had a protein named after it in 2008. The protein, pikachurin, is used in kinetic vision, which, aptly, is the detection of fast objects.

Protein from food
2 We get protein from meat, fish, eggs, nuts and dairy products. We digest the proteins into amino acids, which we later use to replace these proteins in our bodies.

Protein we need
3 Your body makes thousands of proteins every day. For each 1kg you weigh, you typically require 1g of protein. So daily a 70kg man must manufacture 70g of protein for his needs.

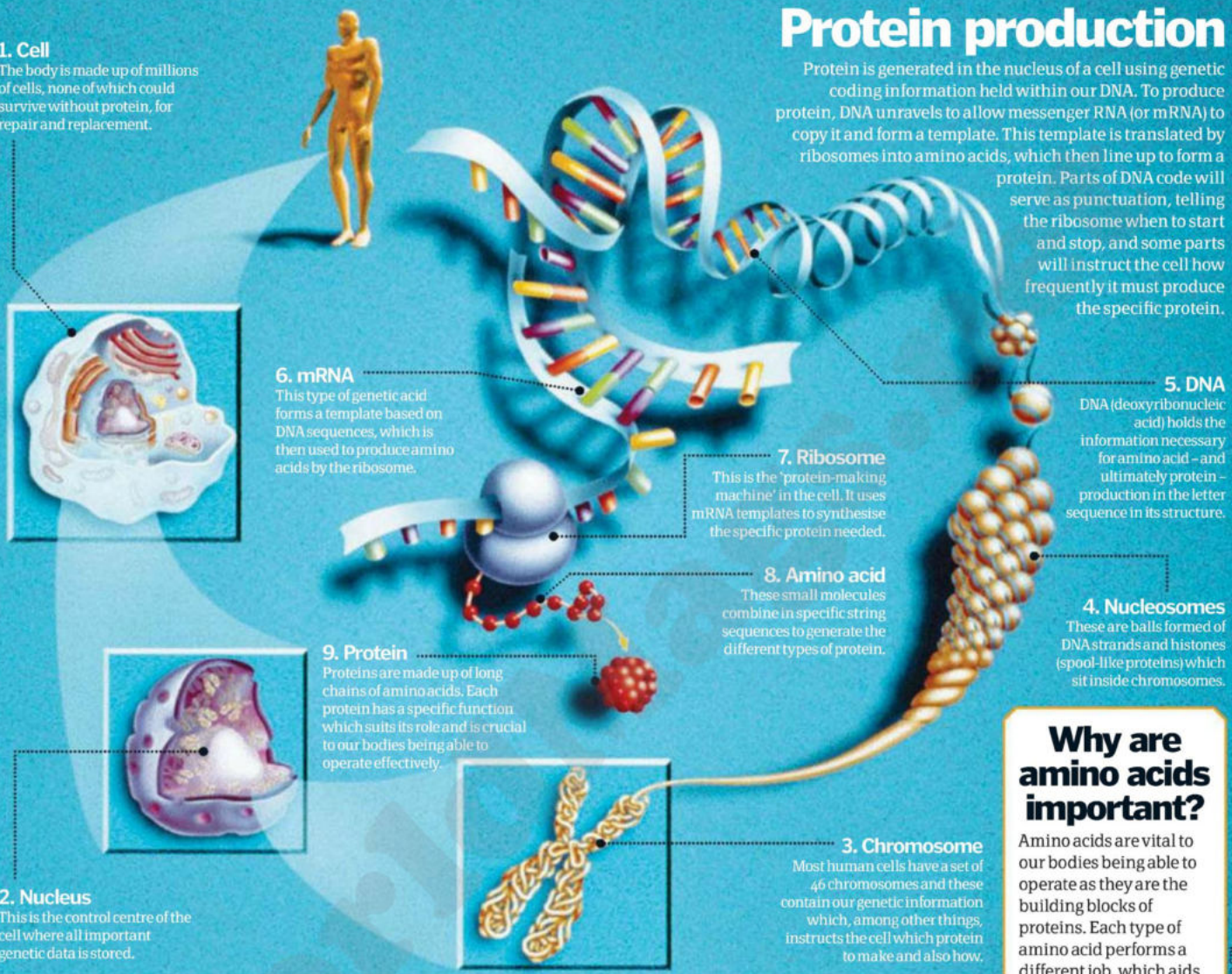
Biuret test
4 The Biuret test is a chemical form of analysis that is used to measure the amount of protein that is present in food. It works out protein levels by analysing the peptide bonds.

Genome studies
5 From studies into the human genomes sequenced so far, it's been discovered that the body contains over 2 million proteins, coded by just 20,000-25,000 genes.

DID YOU KNOW? *Around half of your body's 'non-water' mass is made up of proteins*

Protein production

Protein is generated in the nucleus of a cell using genetic coding information held within our DNA. To produce protein, DNA unravels to allow messenger RNA (or mRNA) to copy it and form a template. This template is translated by ribosomes into amino acids, which then line up to form a protein. Parts of DNA code will serve as punctuation, telling the ribosome when to start and stop, and some parts will instruct the cell how frequently it must produce the specific protein.



1. Cell
The body is made up of millions of cells, none of which could survive without protein, for repair and replacement.

2. Nucleus
This is the control centre of the cell where all important genetic data is stored.

3. Chromosome
Most human cells have a set of 46 chromosomes and these contain our genetic information which, among other things, instructs the cell which protein to make and also how.

4. Nucleosomes
These are balls formed of DNA strands and histones (spool-like proteins) which sit inside chromosomes.

5. DNA
DNA (deoxyribonucleic acid) holds the information necessary for amino acid – and ultimately protein – production in the letter sequence in its structure.

6. mRNA
This type of genetic acid forms a template based on DNA sequences, which is then used to produce amino acids by the ribosome.

7. Ribosome
This is the 'protein-making machine' in the cell. It uses mRNA templates to synthesise the specific protein needed.

8. Amino acid
These small molecules combine in specific string sequences to generate the different types of protein.

9. Protein
Proteins are made up of long chains of amino acids. Each protein has a specific function which suits its role and is crucial to our bodies being able to operate effectively.

Why are amino acids important?

Amino acids are vital to our bodies being able to operate as they are the building blocks of proteins. Each type of amino acid performs a different job, which aids protein activity in the body and determines the protein's primary function(s). Without these, proteins would not be able to help the body with movement, defence against disease, processing food or co-ordinating general growth and development.

There are nine essential amino acids for humans that must be absorbed from external protein sources (eg meat/fish) as they cannot be synthesised by the body. Without the required amount of amino acids, the body can really suffer.

How do we make protein?

Proteins are the building blocks of the human body, but how do we go about manufacturing them?

Proteins are large complex molecules made up of a chain of amino acids. Every cell in our body needs protein to stay alive as it is necessary for tissue repair and replacing dead cells.

They have many other functions as well as aiding cell repair and production including forming antibodies to help fight off disease, forming enzymes which speed up or trigger chemical reactions and co-ordinating processes within the body (via hormone regulation, for instance). Proteins also provide support for cells and form structural elements of the body, such as nails and teeth, as well as facilitating the transportation of some small molecules around various systems.

We build proteins using information encoded in our genetic code. DNA code utilises groups of three letters (a mix of A, G, C and T) and these short sequences, which are known as triplets or codons, then code mRNA templates; these templates are 'translated' by cell ribosomes into amino acids.

Each protein is made up of hundreds of thousands of amino acids, which are in long chains. There are 20 different types of amino acid that can be combined to build a protein and it is the sequence of amino acids that determines each protein's unique three-dimensional structure and its function.

However, not all amino acids can be made by the body. The ones that need to be consumed via our diet are called essential amino acids. If possible, the body will also conserve energy by using amino acids from food rather than producing them itself. Protein deficiency can cause diseases such as kwashiorkor, a form of malnutrition common in poverty-stricken areas.

Pesticides

The science of terminating bugs and other pests explained

Pesticides are mixtures of chemicals and other substances that are used to tackle pests such as weeds. Thousands of different types are in use, and some are even living organisms, such as the bacterium bacillus thuringiensis which is used to control insects. To alter, damage or destroy the life cycle of an unwanted visitor, pesticides interfere in a physical, chemical or biological manner. The three primary methods of application are baiting, fumigating and spraying.

Different pesticides have different forms of attack. Some, like tetramethrin (which is used to kill the household fly), are administered as a spray. Others are absorbed into, say, a weed and remain with it, slowly killing it off from the inside. In addition, insecticides are commonly administered to crops and, when a bug attempts to consume the plant, it will promptly be dealt a lethal dose of the killer substance. Similarly, baiting pesticides, such as rat poison, are also designed to be ingested and will only take effect once they have been absorbed into the bloodstream.

Centre of gravity

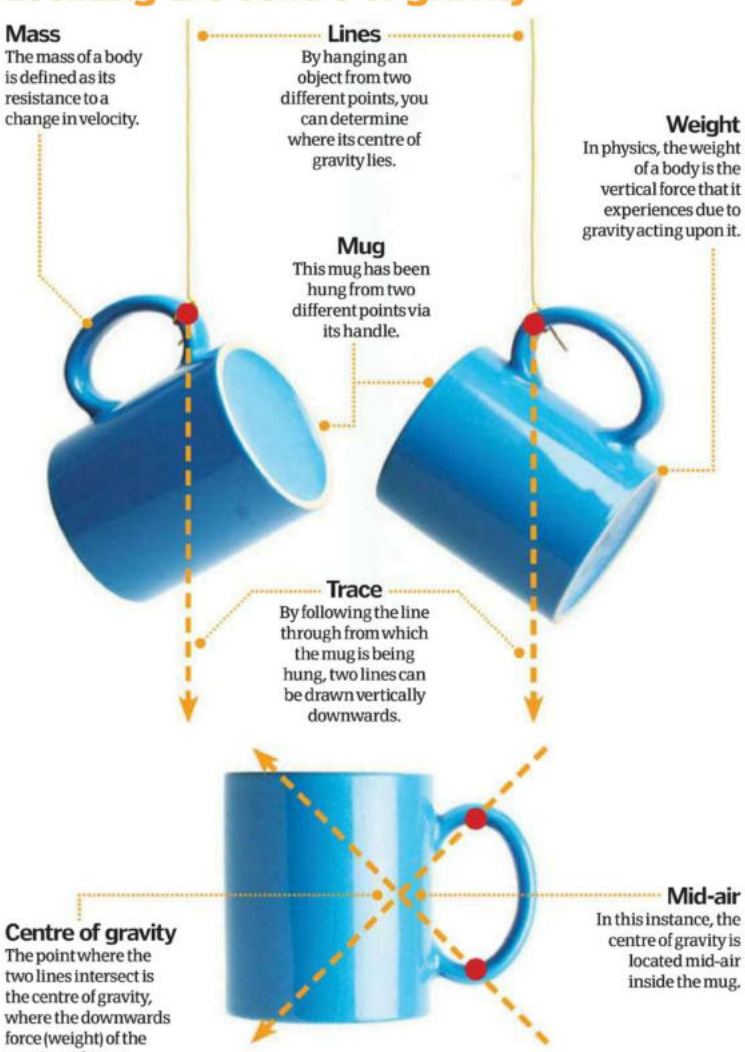
How this basic geometric property determines how stable an object is

An object's mass is defined as the amount of matter within the object. The more matter present the higher the mass will be, and vice versa. However, the mass of all objects is said to act around one point that is known as the centre of gravity. It is around this point that the object can balance, but also where its weight is exerted downwards. In some instances, such as in a horseshoe, the centre of mass is located outside the object's boundaries.

The position of the centre of gravity determines how stable something is. Once the centre of gravity has moved beyond the base area of an object, it will no longer be stable and it will fall to Earth under the force of gravity.

Something with a wide base and low height, such as a Formula 1 car, has a very low centre of gravity in relation to the rest of the object. This means it is very stable and a large force must be applied to tip it over. In contrast, a tall object with a narrow base, such as a bookcase, will have a high centre of gravity and thus only a small force applied towards the top of the object is required to topple it over.

Locating the centre of gravity



AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Visit HIW Daily to see sneezing in action

www.howitworksdaily.com

DID YOU KNOW? *The sudden and deep inhalation just before a sneeze contains approximately 2,500ml (88fl oz) of air*

What happens when you sneeze?

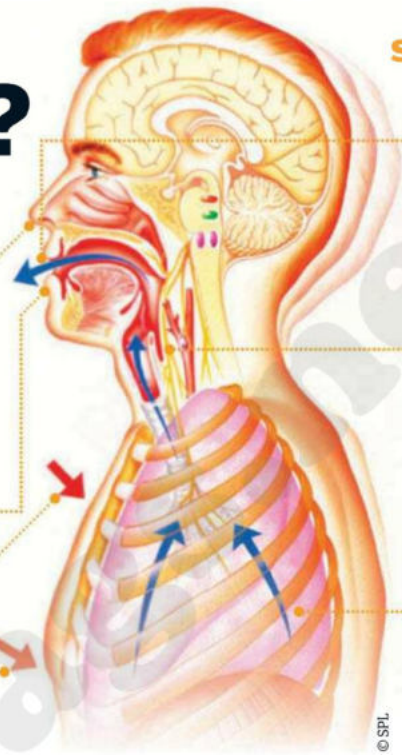
How does this automatic reflex expel unwanted irritants from the body?

When we breathe in, the inhaled air can contain dust, chemicals and other irritants that can be harmful to the body, particularly to organs in the respiratory system like the lungs. While the tiny hairs inside the nostrils (cilia) trap many of these particles, some will often get through. To help you out, your body reacts to try and forcibly expel the offending particles via the sneeze reflex arc.

There are a number of other reasons why we sneeze, including to clear the nasal passages when you have a cold, to expel allergens if you are allergic to something, and interestingly even bright sunlight can cause some people to sneeze; this is specifically called photic sneezing.

When a stimuli is detected by the nerve endings in the nose, impulses are sent to the brain, which initiates a chain of physiological events that enable the body to rid itself of the unwelcome item.

Sneezing step-by-step



1. Irritation
Prior to irritation, the diaphragm muscles are relaxed. When an irritant enters the body, nerve endings in the lining of the nose signal to the brain.

2. Muscles contract
The brain tells the respiratory muscles – including throat, chest and diaphragm – to contract.

3. Intake of breath
Contraction of the diaphragm causes a sharp intake of breath.

4. Air pressure rises
The brain signals to the throat to close. This, combined with the contraction of the abdominal muscles, raises the air pressure inside the lungs.

5. Sneeze
The throat reopens suddenly, explosively forcing air out of the body, making the chest cavity contract sharply. The diaphragm relaxes once again.

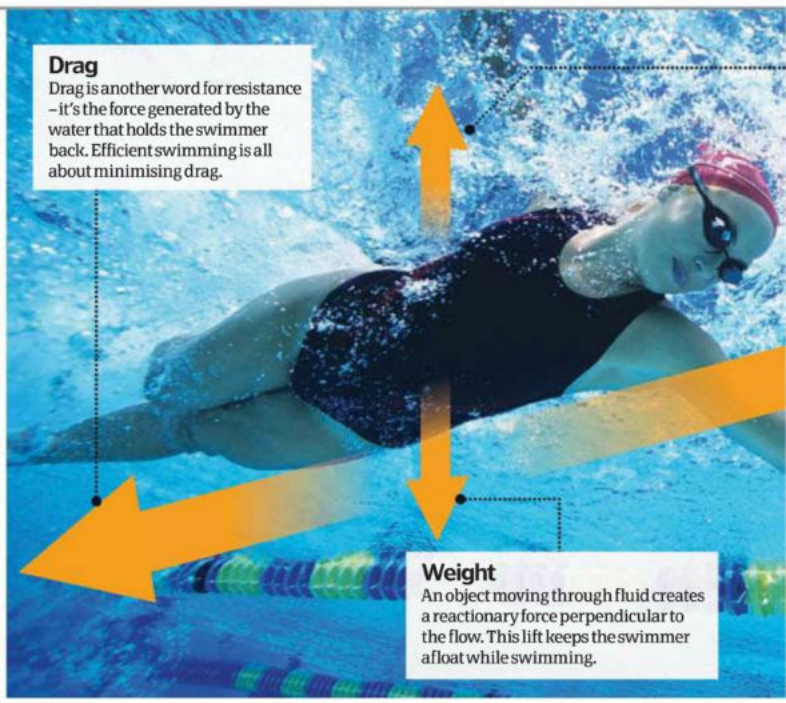
6. Mucus
Together with the offending irritant, saliva and mucus from inside the mouth and nasal cavity are also expelled from the body at up to 160km/h (100mph).

© SPL

"In scientific terms all sports can be boiled down to physics"

Olympic physics revealed

Discover physics in action as we explore the pure science at the heart of several of your favourite Olympic sports events

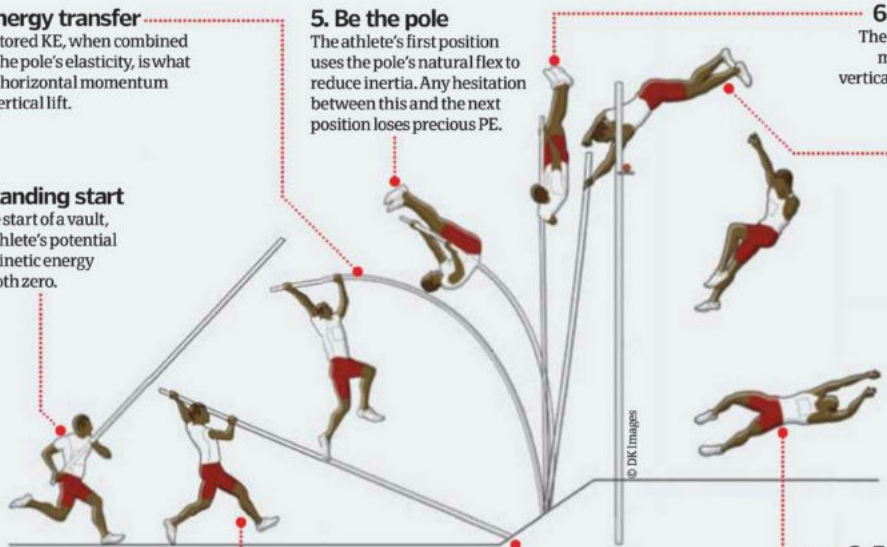


With the Olympics fast approaching, it's not just sport lovers who should be getting excited, but physics fans too. Because whether it's how fast they run, how high they jump or how many records they break, it's the laws of physics that these athletes will really be testing.

In scientific terms all sports can be boiled down to physics – in particular the interaction of natural forces; indeed, any influence that causes an object to change speed, direction or shape. There are many forces at play in the sporting field, from gravity (so common and influential it is known as a 'fundamental' force) to others like friction and resistance, which are explained in Isaac Newton's three laws of motion.

Of course, the athletes are important too, negotiating these forces through a combination of instinct and muscle memory. Ultimately, it's up to you whether you admire Usain Bolt for being an amazing athlete or an unsung master of physics!

So how do these invisible forces contribute to the Olympic events we will be watching this summer? We've taken a look at the pole vault, swimming, the hammer throw and gymnastics, four very different events all governed by the same fundamental rules.



1. Standing start
At the start of a vault, the athlete's potential and kinetic energy are both zero.

2. Building speed
Steady acceleration builds up KE which remains constant until the athlete's speed changes.

3. The plant
Planting the pole firmly in the vaulting box causes both bend and compression in the pole – effectively storing up KE for the next phase.

4. Energy transfer
This stored KE, when combined with the pole's elasticity, is what turns horizontal momentum into vertical lift.

5. Be the pole
The athlete's first position uses the pole's natural flex to reduce inertia. Any hesitation between this and the next position loses precious PE.

6. Body form
The second position mimics the pole's vertical axis – ready for the final push.

7. Down to earth
Whether or not the athlete clears the bar, gravity now takes over to return the vaulter to the mattress.

8. Easy landing
Unlike gymnastics, how the athlete lands is irrelevant – their work is done.

The pole vault

Understanding the science behind sport is hard enough when it's just man versus physics; throw another object into the mix and things get even more complicated.

Pole vaulting, for instance, is based on the same principles as high jump: that is, converting linear momentum into vertical lift. What makes it different and harder to calculate is the pole, a carbon-fibre tube which is designed to first absorb and then increase kinetic energy (KE) as it bends and flexes. Meanwhile, the athlete still needs perfect timing to ensure the run-up, the plant and the final push over the bar conserve as much potential energy (PE) as possible through these key transitions.

It's a feat that seems more incredible the more you appreciate how many elements have to go just right to achieve the perfect vault – one reason why Sergei Bubka's world record of 6.14 metres (20.14 feet) has stood since 1994.

0.8sec

USAIN BOLT

Between 2007 and 2009, Usain Bolt lowered the 100 metres world record by an average 0.8 seconds per year. If that level of progress continued, running the 100 metres would take literally no time at all in under 200 years.

DID YOU KNOW? *Steve Redgrave CBE is the only Olympian to win gold at five Games in a row: 1984, 1988, 1992, 1996 and 2000*

Swimming

When you watch someone swimming, it's easy to think they are dragging themselves through the water. However, on the contrary, they are being pushed.

Newton's third law states that to every action force there is an equal, but opposite, reaction force, meaning that as the swimmer kicks with their legs or pulls with their arms, force is applied downwards and backwards, prompting a reactive force from the water pushing the body up and forwards.

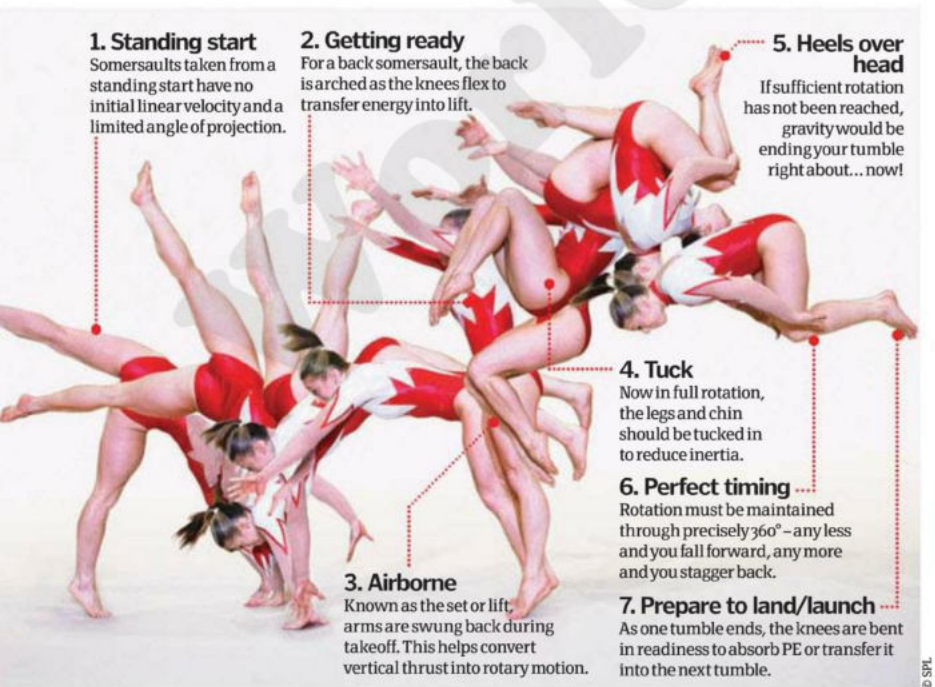
Hardly surprising then that the swimmer's top priority is to reduce drag by any means possible – from perfecting dives to developing new suit materials and designs that minimise surface area when in the water.

But that's not all. The faster an object travels through any element, the greater the resistance it encounters. As water is 773 times as dense, and 100 times more resistant, than air, top swimmers need to work harder than, say, top sprinters. Conversely, because of buoyancy, they are less likely to get injured.

Somersault

Though rarely seen on its own, the somersault lies at the heart of many Olympic gymnastics disciplines. Somersaults are all about maintaining angular momentum (inertia times velocity) while the body is in the air. During the tumble itself, the arms and legs are tucked closely into the body, helping to reduce inertia as it rotates through 360 degrees in either direction. The more height and velocity achieved through each tumble, the more rotations can be completed before gravity has time to pull the athlete back down.

This explains why a single forward or back somersault can be made from a standing start but multiple tumbles, twists and pikes always require a run-up. This increases linear velocity and changes the angle of projection – allowing for several longer, faster and higher tumbles.



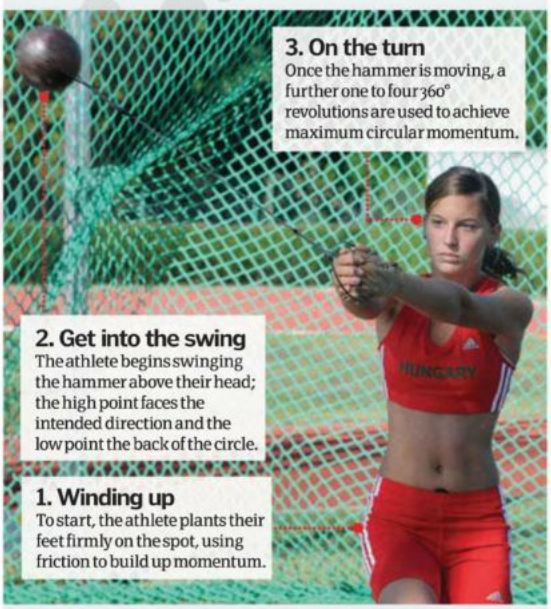
© SPL

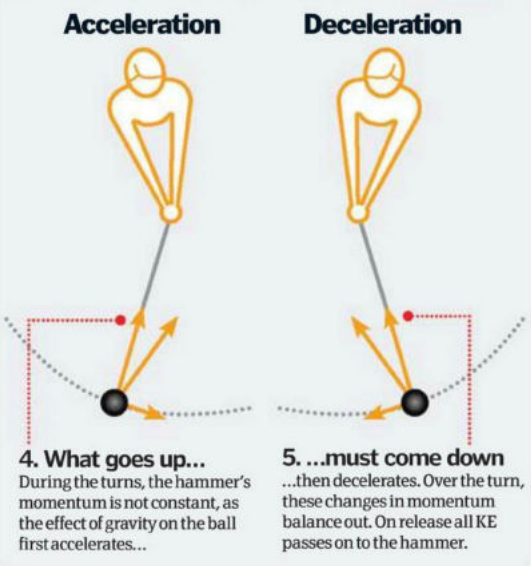
The hammer throw

The hammer consists of three separate and independently moving parts: the handle, 1.2-metre (3.9-foot) chain and, for men, 7.3-kilogram (16-pound) ball; the women's hammer weighs almost half that at four kilograms (8.8 pounds). Each part reacts to the same forces in slightly different ways.

The perfect throw is split into three key phases. The first is the winds, where the athlete swings the hammer around their head to build up circular momentum. The second is the turns, one to four rotations that maximise the hammer's PE. And finally the release, which is about judging the right time, angle and height to achieve maximum velocity as a measure of the hammer's kinetic energy.

Additionally, like all throwing and shooting events, wind resistance can play its part. A strong headwind is capable of reducing a throw's potential length by several centimetres.





Welcome to... SPACE

We've got something for everyone in the Space section this issue, with articles on the highest mountain range on Venus, the only material that can escape black holes and a look at the first communications satellite which is still in orbit around Earth. But to kick off, we explain what makes the world go round, quite literally!

67 Maxwell Montes

68 Telstar 1

68 Hawking radiation

64 Why Earth spins
67 Maxwell Montes
68 Hawking radiation
68 Telstar 1
70 Cosmic expansion

LEARN MORE

Why does the Earth spin?

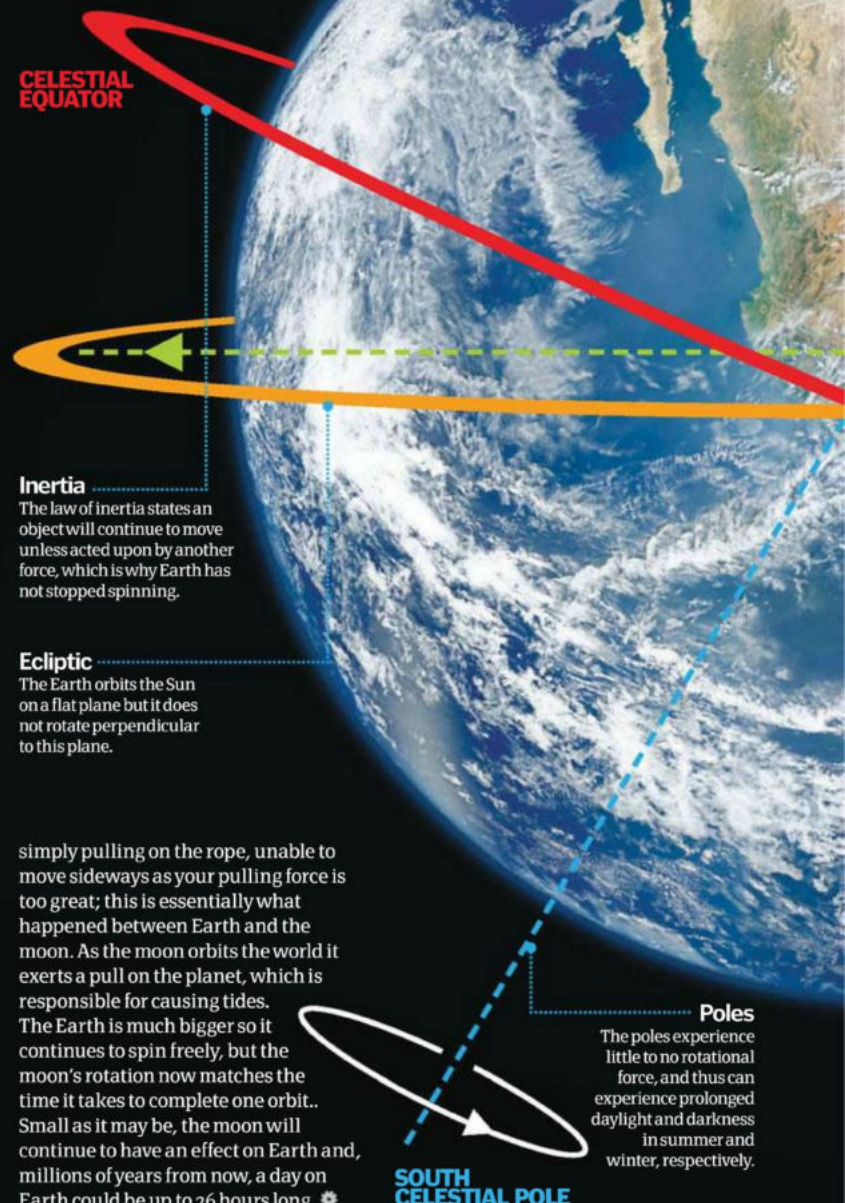
Find out why our planet has rotational movement

The story of why the Earth spins goes back to the formation of the solar system. In the beginning, roughly 4.7 billion years ago, the solar system was a large swirling cloud of dust and gas. Over time this gradually coalesced into stars and planets, being drawn into these shapes by gravity. This motion of being pulled inwards increased the angular momentum of the various bodies, and thus caused them to start rotating faster.

Consider an ice skater spinning with their arms outstretched. As they spin, they bring their arms inwards. Doing so increases their angular momentum, which makes them spin faster. The same is true for when the Earth first formed. As the dust and gas was compressed into one solid mass, the total mass of the object became more confined and subsequently began to rotate more and more rapidly.

The law of inertia states that anything stationary or moving with a constant speed wants to continue doing so until it is acted upon by another body/force. Considering the Earth rotates in space, which is a vacuum, there is nothing to drastically slow the Earth down which is why it continues to spin. Interestingly, early in its formation, the world spun up to five times faster than it does now – so we know Earth has lost some speed.

The culprit is the moon. It is our own natural satellite that has caused the planet to slow down, via something known as tidal locking. The moon at the moment is tidally locked to the Earth – that is, the same face always looks towards us, but it was not always so. When the moon first came into orbit around the Earth it was also spinning. To understand tidal locking, imagine that you and a friend both pull on a piece of rope, but at the same time you spin in a circle around a pivot at the centre of the rope. As you tug harder, you are eventually able to spin less and less fast. Eventually, you will be stuck simply pulling on the rope, unable to move sideways as your pulling force is too great; this is essentially what happened between Earth and the moon. As the moon orbits the world it exerts a pull on the planet, which is responsible for causing tides. The Earth is much bigger so it continues to spin freely, but the moon's rotation now matches the time it takes to complete one orbit.. Small as it may be, the moon will continue to have an effect on Earth and, millions of years from now, a day on Earth could be up to 26 hours long.



RECORD BREAKERS
FASTEST PULSAR

43,000RPM

SPEEDY PULSAR

The object with the highest rotation rate in the universe is the pulsar PSR J1748-2446ad, which completes 716 spins per second!

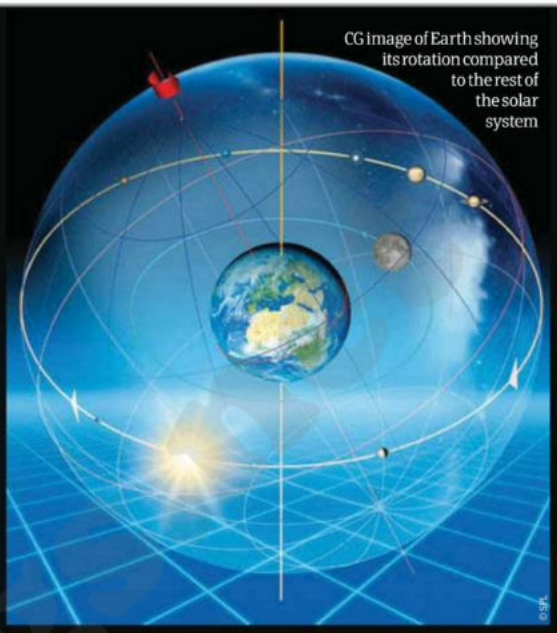
DID YOU KNOW? The Earth now rotates at 1,674km/h (1,040mph), but was five times faster early in its formation

Axis
The Earth rotates around an axis that is about 23.5° to the vertical line through the planet perpendicular to its orbital plane.

Angle
The angle of the Earth's rotation has not always been the same; some research suggests it changes up to 1° every million or so years.

Seasons
The tilt of the Earth to the Sun determines the season experienced in each hemisphere, with a tilt towards or away leading to hot and cold seasons, respectively.

Equator
The true equator of the Earth passes perpendicular to the axis. This is the part of our planet that has the greatest rotational speed.


CG image of Earth showing its rotation compared to the rest of the solar system

Getting in a spin

The rate of rotation of a body is determined by the rapidity of its formation (ie a faster collapse means a greater angular momentum is conserved). Impacts from meteorites and the gravitational effect of natural satellites can eventually slow the body, be it a planet or a star. In our solar system, the distance to the Sun also determines how fast a planet will spin – the closer a planet is, the slower it will go and vice versa.

This is an effect known as tidal locking, which is demonstrated by moons that are tidally locked to their host planets. They begin spinning but eventually slow down and finally are gravitationally locked, so the same face always looks towards their host planet, much like our moon.

The fastest spinning objects in the universe are pulsars. These are neutron stars that are left behind after a giant star goes supernova. Pulsars have a huge amount of mass confined into a very small space, sometimes less than a few dozen kilometres across. For that reason they have a very high angular momentum; some rotate up to 1,000 times a second.

"The closer a planet is, the slower it will go and vice versa. This is an effect known as tidal locking"

Rotation comparison

How fast do other bodies in the solar system spin?

*A minus indicates the rotation is backwards relative to Earth

HOW SCI-FI ARE YOU?

Use the SciFiNow flowchart to find out...

START

HAVE YOU SEEN STAR WARS?
- NO → END
- STUPID QUESTION → DID HAN SHOOT FIRST?

DID HAN SHOOT FIRST?
- YES. YES. YES → DO YOU WANT TO BELIEVE?
- NAH. IT WAS GREEDO → IS MEMORABILIA FOR DESKS OR KIDS?

IS MEMORABILIA FOR DESKS OR KIDS?
- KIDS → WOULD YOU PREFER AN IPAD OR ZIGGY?
- DESKS → WHAT MAKES TIME TRAVEL POSSIBLE?

WOULD YOU PREFER AN IPAD OR ZIGGY?
- IPAD → NOWHERE NEAR GEEKY ENOUGH. BUT THERE IS HOPE
- ZIGGY → WHAT MAKES TIME TRAVEL POSSIBLE?

DO YOU WANT TO BELIEVE?
- YES I DO → WOULD YOU PASS A VOIGHT-KAMPFF TEST?
- BELIEVE IN WHAT? → DO THESE MEAN ANYTHING TO YOU: 4,8,15,16, 23, 42

WOULD YOU PASS A VOIGHT-KAMPFF TEST?
- NATURALLY → WHAT DOES OCP STAND FOR?
- A WHAT-KAMPFF? → DO YOU KNOW WHAT EXACTLY THE TROUBLE WITH TRIBBLES IS?

DO THESE MEAN ANYTHING TO YOU: 4,8,15,16, 23, 42
- LOTTERY PREDICTION? → WHAT MAKES TIME TRAVEL POSSIBLE?
- OF COURSE → UNOBTAINIUM OR ADAMANTIUM?

DO YOU KNOW WHAT EXACTLY THE TROUBLE WITH TRIBBLES IS?
- THEY SMELL A BIT? → UNOBTAINIUM OR ADAMANTIUM?
- SURE → DO YOU PLAY WITH YOUR MASHED POTATO?

WHAT DOES OCP STAND FOR?
- HAVEN'T A CLUE → DO YOU PLAY WITH YOUR MASHED POTATO?
- OMNI CONSUMER PRODUCTS → HOW DO YOU SPELL 'RECALL'?

HOW DO YOU SPELL 'RECALL'?
- NOT LIKE THAT → WHAT MAKES TIME TRAVEL POSSIBLE?
- LIKE THAT → WHERE IS BABYLON 4?

WHAT MAKES TIME TRAVEL POSSIBLE?
- NOTHING → SOMEWHERE INSIDE YOU IS A NERD TRYING TO GET OUT
- FLUX CAPACITOR → UNOBTAINIUM OR ADAMANTIUM?

UNOBTAINIUM OR ADAMANTIUM?
- ADAMANTIUM → HOW DO YOU MAKE A SOYLENT GREEN?
- UNOBTAINIUM → WHO IS HAL JORDAN?

DO YOU PLAY WITH YOUR MASHED POTATO?
- YEP → WHERE IS BABYLON 4?
- NEVER → HOW DO YOU MAKE A SOYLENT GREEN?

WHERE IS BABYLON 4?
- WITH PEOPLE → HOW DO YOU MAKE A SOYLENT GREEN?
- DUNNO → DO YOU KNOW WHAT THE CULTURE IS?
- LOST IN TIME → WHAT CLASS OF PLANET IS VULCAN?

HOW DO YOU MAKE A SOYLENT GREEN?
- PAINT IT? → FANCY A TRIP ON THE NOSTROMO?

WHO IS HAL JORDAN?
- NO IDEA → WHAT DOES V STAND FOR?

WHAT DOES V STAND FOR?
- VIMTO → SOMEWHERE INSIDE YOU IS A NERD TRYING TO GET OUT
- VISITORS. OR VENDETTA. WHICHEVER → FANCY A TRIP ON THE NOSTROMO?

FANCY A TRIP ON THE NOSTROMO?
- ISN'T THAT A VAMPIRE? → SOMEWHERE INSIDE YOU IS A NERD TRYING TO GET OUT
- ARE YOU MENTAL? → WHAT WAS SUPPOSED TO HAPPEN ON 27 AUGUST 1997?

WHAT WAS SUPPOSED TO HAPPEN ON 27 AUGUST 1997?
- SUNDAY TIMES SUPPLEMENT? → DO YOU KNOW WHAT THE CULTURE IS?
- A PARTY? → THE FORCE IS WITH YOU. BUT YOU MUST TRAIN HARDER

DO YOU KNOW WHAT THE CULTURE IS?
- UPPER? → WHAT CLASS OF PLANET IS VULCAN?
- JUDGMENT DAY → WHAT WAS SUPPOSED TO HAPPEN ON 27 AUGUST 1997?
- YES → CAN YOU NAME THE FIVE?

WHAT CLASS OF PLANET IS VULCAN?
- EVERYBODY KNOWS THAT... → FANCY A TRIP ON THE NOSTROMO?
- M → CAN YOU NAME THE FIVE?

CAN YOU NAME THE FIVE?
- SURE CAN'T → IMPRESSIVE. YOUR SCI-FI KNOWLEDGE IS PRETTY AMAZING
- SURE CAN → WE BOW DOWN TO YOU, MASTER OF ALL GEEKDOM

MORE SCI-FI THAN YOU THOUGHT? JOIN OTHER LIKE-MINDED INDIVIDUALS EVERY MONTH AND READ SCIFINOW.

BECAUSE SCI-FI'S FOR EVERYONE

1. EARTH

Mount Everest
The tallest mountain on Earth is Everest in the Himalayas between Nepal and Tibet. It reaches 8.85 kilometres (5.5 miles) at its highest point.

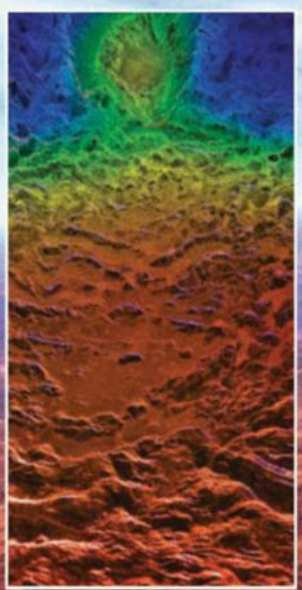
2. IAPETUS

Equatorial ridge
The equatorial ridge on Iapetus, one of Saturn's moons, rises up to 20 kilometres (12.5 miles) and runs along the centre of the moon's hemisphere.

3. MARS

Olympus Mons
The tallest mountain in the solar system is Olympus Mons, which stands 24 kilometres (15 miles) tall on the Red Planet.

DID YOU KNOW? *The Maxwell Montes chain spans an area equivalent to the distance between London and Aberdeen*



A CG rendering of Maxwell Montes's eastern slope

The statistics...

Maxwell Montes

Height: 11km (6.8mi)
Diameter: 797km (495mi)
Length: 853km (530mi)
Temperature: 380°C (716°F)
Pressure: 59 atmospheres (59N/sq cm; 867psi)

A re-creation of Maxwell Montes based on data from the Magellan radar-mapping spacecraft

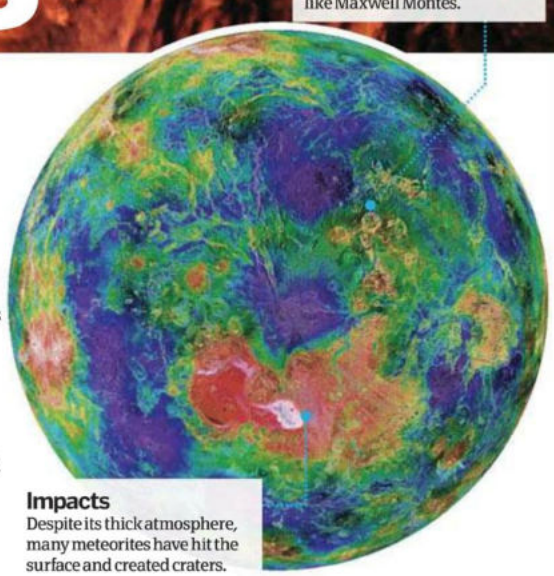
Maxwell Montes

We take a closer look at the highest peaks on Venus

Maxwell Montes is a giant mountain range located on Ishtar Terra, which is the most northern of the two major highlands on Venus. It is a part of the Lakshmi Planum, a large plain that likely resulted from smooth lava flows on the surface of the planet. Maxwell Montes rises to an elevation of 11 kilometres (6.8 miles) at the highest point and is 797 kilometres (495 miles) in diameter. It has very steep slopes, particularly on the chain's western side, likely a result of how the lava flowed in the past.

Venus is the hottest planet in the solar system. Its incredibly high surface temperature can be accounted for by its dense atmosphere, which retains almost all of the sunlight that passes through it. However, the presence of dormant volcanoes like Maxwell Montes suggests that Venus was once a volcanically active planet, and indeed these volcanoes may have been major contributors to the thick atmosphere that currently surrounds our closest neighbour. Precisely when Venus was volcanically active in its 4.7 billion year lifetime is currently a matter of debate.

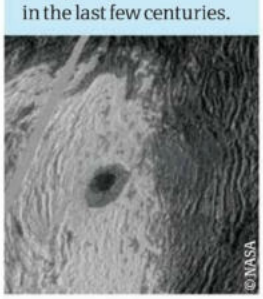
Volcanic
The terrain of Venus is littered with signs of dormant volcanoes like Maxwell Montes.



Impacts
Despite its thick atmosphere, many meteorites have hit the surface and created craters.

Cleopatra crater

This impact crater on Venus is found on the Ishtar Terra mountain range on Maxwell Montes. It stretches 100 kilometres (62 miles) in diameter and has two discernible rings inside. At first it was thought to be the remains of a volcano, but new research (and the discovery of the rings) indicate it was formed from a meteorite impact. Its dark centre is covered in a fine dust, while the outer ring is made of the ejected debris from the initial impact. It's thought to have formed in the last few centuries.



"Telstar 1 relayed its first public pictures on 23 July 1962... of the Statue of Liberty and the Eiffel Tower"

A CG rendering of a black hole firing out a jet of Hawking radiation

© NASA

Hawking radiation

Find out what can escape from black holes, the universe's ultimate prisons

According to quantum physics, throughout the universe there are endless pairs of subatomic particles that appear from nothingness and almost immediately disappear again. One of these has a negative mass and the other positive, which is why they instantly annihilate each other, but their existence for any determinable length of time is theoretically impossible.

However, Professor Stephen Hawking proposed that around a black hole something rather unusual happens. As in open space these two subatomic particles form, however they do not destroy each other. Instead, the negative mass particle is pulled into the black hole, while the positive one is fired out.

The latter exits in the form of measurable radiation, which is constantly ejected. This was coined 'Hawking radiation', and explains why black holes appear to glow extremely brightly as opposed to being totally dark. Interestingly, the negative-mass particles slowly eat away at the mass inside the black hole. Eventually they consume all of the mass within the entity, causing it to collapse and subsequently explode. While this occurrence has never actually been observed, it's now widely believed to be the eventual fate of almost all black holes.

No dice

Einstein wasn't a fan of quantum physics theories. Believing the universe to be more ordered, he once quipped: "God does not play dice." The discovery of Hawking radiation, however, led Professor Hawking to rebut, "God not only plays dice, but he sometimes throws them where they cannot be seen."

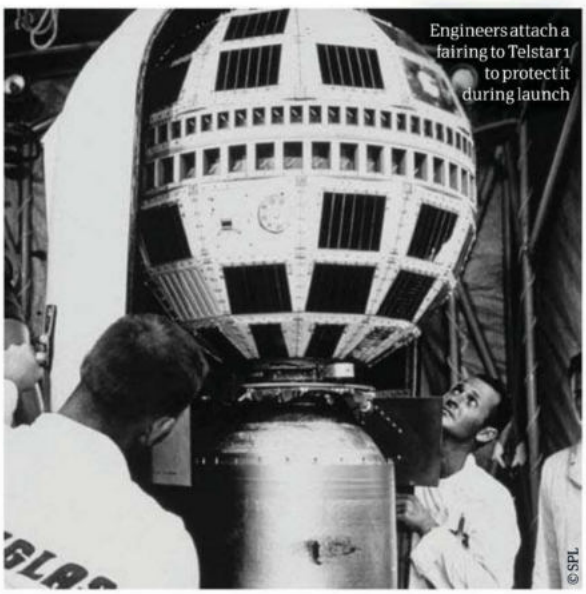
Telstar 1

How the world's first active communications satellite worked

Telstar 1 was a collaboration between NASA and American Telephone & Telegraph (AT&T), launched atop a Delta rocket on 10 July 1962. For the first time ever, it provided audio communication and simultaneous video between the USA, Europe and Japan, becoming the first active communications satellite capable of transmitting a signal.

The first passive communications satellite was NASA's 1960 Echo 1 balloon, which bounced signals off its Mylar structure that could be received around the world. Telstar 1 completed one orbit of the Earth in two and a half hours, which meant that it could only relay signals between two places for up to 40 minutes during each orbit when it was in line with more than one ground station.

Telstar 1 relayed its first public pictures on 23 July 1962, broadcasting images of the Statue of Liberty and the Eiffel Tower. It eventually went out of service on 21 February 1963. The cause of its demise was a series of nuclear bomb tests by the USA and USSR at the height of the Cold War, with the radiation from several explosions energising the Earth's Van Allen Belt and overwhelming Telstar 1's fragile transistors. However, today Telstar 1 remains in orbit around the Earth, the longest orbiting manmade satellite.



Engineers attach a fairing to Telstar 1 to protect it during launch

© SPL

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Forensics
Crazy Machines
Rocketry

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"For people who want an aquarium, but think it's too much work"

At last, an aquarium for busy people. biOrbs have built-in lighting and simple filtration that really works. The filter cartridges are easy to change and it only takes a few seconds.

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Why they're made from acrylic, not glass
Acrylic is ten times stronger than glass. Why's that so important? Just ask anyone who's broken a glass aquarium and flooded their home.

"it's like watching fish in high definition"

Did you know it's also noticeably clearer? Acrylic has a transparency rate of 93% but glass only allows 70% of light to pass through. With a biOrb it's been said that *"it's like watching fish in high definition"*.

Inside the patented filter.
Air driven filtration creates vigorous water flow. This maintains oxygen saturation.

Circular water flow then collects fish waste on its way down and traps it in the easy-to-change cartridge.

The cartridge needs changing about once every six weeks and takes only seconds to do.

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You'll also get step-by-step instructions to help you on your way. Just sit back and enjoy the magic of keeping fish.

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"Objects further away from us are moving faster than those that are closer"

Cosmic expansion

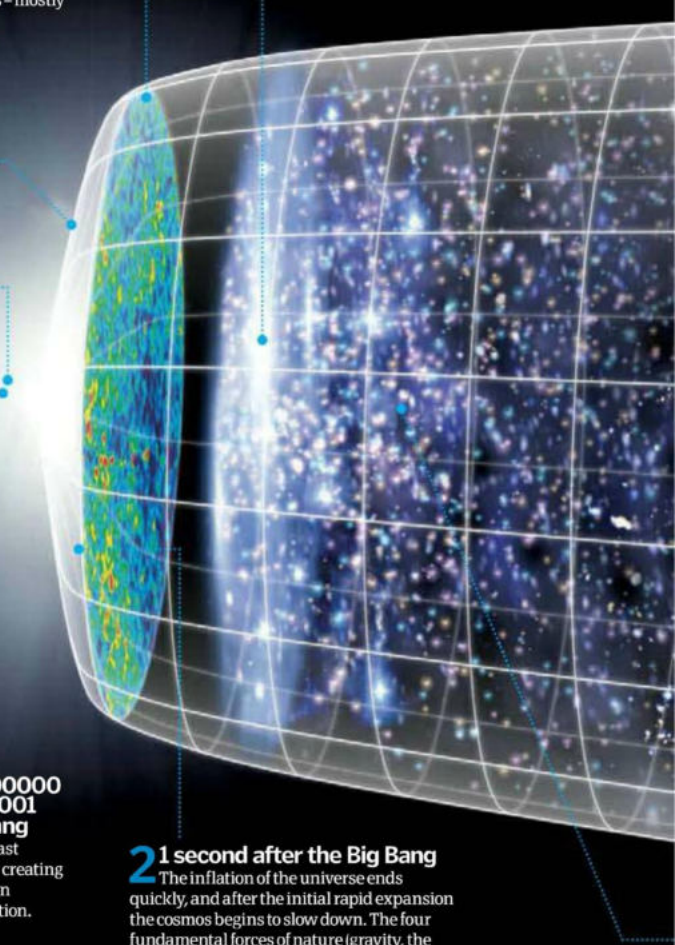
Is the universe expanding and, if so, what will become of it?

The expansion of the universe was first theorised by Alexander Friedmann in 1922, who derived the Friedmann equations to show that the cosmos could be getting bigger. His theory was confirmed in 1929 by Edwin Hubble, who was the first to observe that distant galaxies appeared to be moving away from us. Since then, it has generally been accepted that the universe is expanding. Some think that it will expand faster and faster, some think that it will reach a stable flat state and others believe it will eventually start to contract, culminating in a 'Big Crunch'. But what's for certain is that our observations clearly show that for now it is growing, and objects further away from us are moving faster than those that are closer.

A good way to imagine cosmic expansion is in a smaller, more everyday scenario. Imagine that you have a deflated balloon, and on it you draw lots of dots. As you blow up the balloon all of the dots start to move away from one another, but there is no central point from which all the dots move. Indeed, dots further away from one another appear to move at a greater speed and vice versa. This is essentially what is happening in the universe, but on an infinitely larger scale, with entire galaxies appearing to move away from one another. There is, however, no centre of the cosmos. In other words, if we stood on a planet in another galaxy, we would observe the same phenomenon as on Earth – namely that everything is moving away from us, with further objects moving more rapidly.

Every galaxy has something known as red shift, which is the primary method through which the expansion of the universe was confirmed. This can be best explained by comparison to the Doppler effect. When a police car drives past you with its siren on, the sound waves are compressed and subsequently expanded as it zooms by. As it comes towards you the sound waves are squashed, while as it moves away the waves are stretched. This decreases and increases the frequency of the sound waves, respectively. The same thing happens with light coming from a distant galaxy. As the galaxy is moving away from us, the light from it appears to stretch towards the red end of the electromagnetic spectrum. The further away – and thus the faster a galaxy is moving from us – the greater the red shift will be. As an aside, if a galaxy is spinning, the side moving towards us, will be squashed towards the blue end of the spectrum, known as blue shift, although this is unrelated to the expansion of the universe.

One of the most compelling pieces of evidence for cosmic expansion was something known as Olbers' Paradox. In 1823 German astronomer Heinrich Wilhelm Olbers posited if the universe was infinite and stationary, then the night sky should be as bright as a star because all stellar light should be constantly entering our atmosphere. Olbers suggested, therefore, that the night sky was black as the universe was expanding. The light from distant stars was being stretched and bent and, as a result, Earth was not being bombarded by constant light. Coupled with direct observations of distant galaxies, it's clear the universe is growing, however what its eventual fate will be is still very much up for debate.



1 0.00000000000000000000000000001 seconds after the Big Bang
Space and time is generated in a vast explosion known as the Big Bang, creating all matter and energy in the known universe via a process called inflation.

2 1 second after the Big Bang
The inflation of the universe ends quickly, and after the initial rapid expansion the cosmos begins to slow down. The four fundamental forces of nature (gravity, the strong force, the weak force and the electromagnetic force) take shape and hold the universe together.

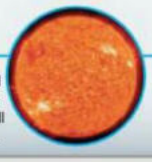
3 3 minutes after the Big Bang
The universe as we know it begins to take shape. Protons and neutrons come together to form basic matter and elements – mostly hydrogen and helium.

4 500,000 years after the Big Bang
The universe remains as a huge cloud of hot expanding gas. It eventually cools to a critical threshold when celestial bodies can form. Photons from this period remain as cosmic microwave background radiation, which we can still observe today.

KEY DATES
COSMIC LIFE CYCLE

13.7bn yrs ago
The universe is born. A vast explosion called the Big Bang creates everything in the known universe.

5bn yrs ago
Our Sun is born from a cloud of gas in the Milky Way. It is surrounded by debris that will later form the solar system.



3bn yrs from now
It is estimated that around this time the Milky Way will collide with the nearby Andromeda galaxy.

1 trillion yrs from now
At this point galaxies will no longer exist due to cosmic expansion, leaving rogue stars, planets and dispersed matter.

10^{100} yrs from now
By now, all matter will have decayed. Only subatomic particles remain so the universe can be considered dead.

DID YOU KNOW? *Einstein, who originally theorised a static universe, later declared this to have been one of his worst mistakes*

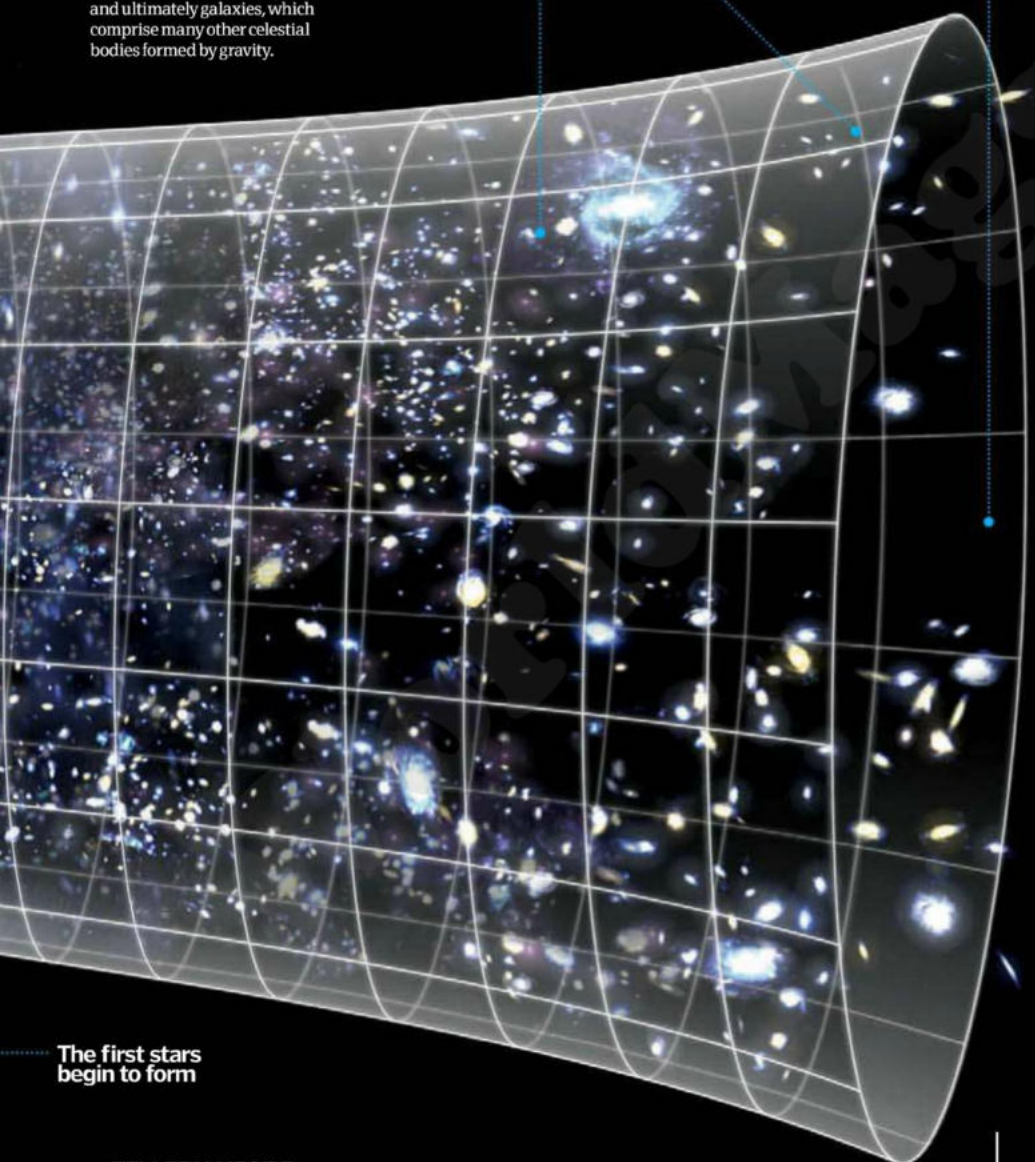
The evolving universe

What's happened since the Big Bang?

6 Present day (13.7 billion years after the Big Bang)
The universe has cooled to 2.7 Kelvin (-270°C/-455°F) but continues to expand. It is unknown if it will continue to grow forever, become stable or eventually contract.

Dark energy accelerated expansion

5 1 billion years after the Big Bang
The gravitational pull of matter in the universe draws together clouds of primordial gas. This gas becomes more and more dense until a new wave of stellar ignition occurs, producing stars and ultimately galaxies, which comprise many other celestial bodies formed by gravity.



The first stars begin to form

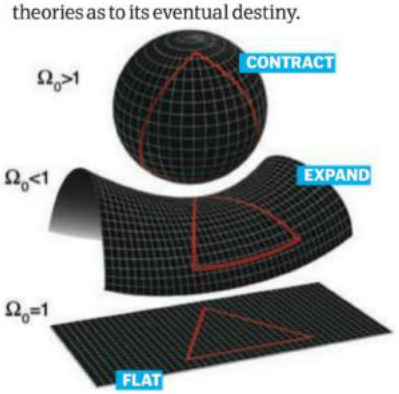
13.7 BILLION YEARS

Fate of the cosmos

What will become of the universe in the future?

The rate of expansion of the universe is determined by the Hubble Constant, Ho, the equation for which is also a measure of how old the cosmos is. By calculating the gravitational strength of galaxies in the universe, and determining the rate of acceleration of each, the shape of the cosmos can be estimated.

The fate of the universe is ultimately governed by its density, but this is currently unknown. A benchmark known as the 'critical density' – a point at which the universe can be said to be in its final stable state – provides us with three main theories as to its eventual destiny.



Contract
A density greater than the critical density will lead to a 'Big Crunch'. The universe's expansion will slow and the gravity in the cosmos will result in a contraction. All matter will move towards everything else at a faster and faster rate until the reverse of the Big Bang occurs, when everything is compressed into an infinite point.

Expand
If the density of the universe is less than the critical density, then the universe will expand forever. However, under this theory, everything in the cosmos will continue to move away from everything else until the universe is so sparse that nothing can interact with anything else, ultimately leading to its demise.

Flat
If the density of the universe is equal to the critical density, then the universe will eventually become stable. The expansion of the cosmos will slow and come to a halt, but it will not reverse, so everything will remain stable and the universe could potentially go on forever.

Your favourite magazines n

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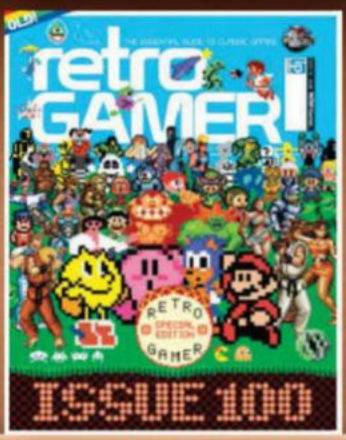

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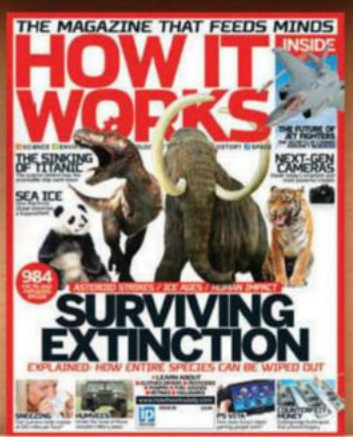
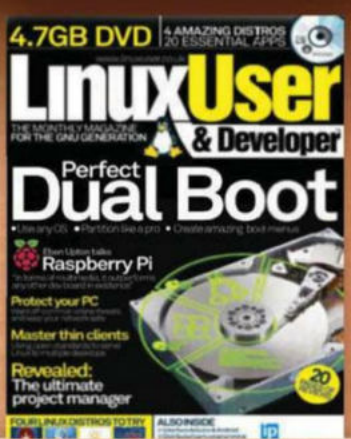


How It Works



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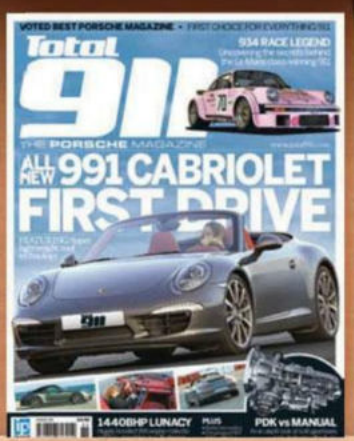

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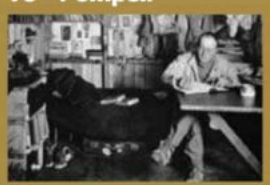
Welcome to... HISTORY

It's one of the 20th century's most iconic events and even now, a hundred years later, Titanic still features prominently in the public psyche. This issue find out not only how the disaster played out but also the tech that made this ship so advanced. On a similar note, we also look at the Terra Nova, the epic expedition to the South Pole, which also ended in tragedy.

78 Hallmarks

79 Pompeii



80 Scott's last voyage

74 RMS Titanic
78 Hallmarks
79 Pompeii
80 Scott of the Antarctic

LEARN MORE

The sinking of Titanic

One hundred years on, the story of how one of the world's greatest ships came to sink remains as mystifying as it is tragic. How It Works sets out to uncover what happened...


THE NEW YORK HERALD.
THE TITANIC SINKS WITH 1,800 ON BOARD; ONLY 675, MOSTLY WOMEN AND CHILDREN, SAVED

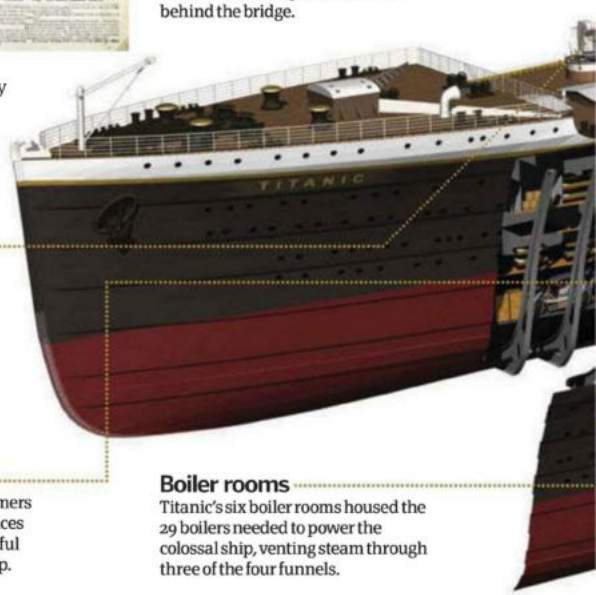
The front page of *The New York Herald* reporting on the tragedy

RMS Titanic was an Olympic-class passenger liner owned by British shipping company White Star Line and constructed at the Harland and Wolff shipyard in Belfast, Northern Ireland. Titanic was the largest ship in its class, along with its sister ship the Olympic, and was capable of holding over 2,000 people. Its maiden voyage from Southampton, UK, to New York began on 10 April 1912. However, four days into crossing the Atlantic the ship glanced an iceberg and sank within three hours, resulting in one of the worst maritime tragedies in history. The remarkable story of how it sank is even more surprising considering some of the technological advances used on the ship, but despite being one of the most high-profile disasters ever, many mysteries around the actions of the senior officers on that fateful night remain unanswered and will likely stay so forever.

RMS Titanic was the second of three Olympic-class ships, the others being RMS Olympic (1910-1935) and RMS Britannic (sunk by a mine in 1916 after two years in service). For their time they were the largest ocean-liners in operation, and by far the biggest vessels in White Star Line's 1912 fleet of 29 ships. The three were all but identical in design save for a few very minor differences – mostly adjustments to Titanic to make it more luxurious for first-class passengers. They were built as a result of a rivalry between White Star Line and Cunard Line, the latter of which had just produced the fastest passenger ships around (the Lusitania and Mauretania). However, White Star Line's chairman, J Bruce Ismay, decided in 1907 to focus on size rather than speed, culminating in the building of these three behemoths.

The ships were constructed at Harland and Wolff in Belfast, which had been contracted to build ships for White Star Line for the previous five decades. The shipbuilder was given an almost unlimited budget to spend on the project and, by the end, Titanic and Olympic carried a combined cost of approximately £3 million ($4.75 million). Construction of Titanic began on 22 March 1909, just a few months after her sister the Olympic. Over 1,500 men worked on the two ships, with as many as eight dying during construction. In a

Bridge
The bridge and wheelhouse were in front of the officers' quarters towards the bow of the ship, with the former rising 2.4m (8ft) above the deck and the latter situated just above and behind the bridge.



Lifeboats
Titanic was equipped with enough lifeboats to save half the people on board, but due to the policy of 'women and children first' many of them departed half empty.

Workers
200 firemen, stokers and trimmers were needed to keep the furnaces burning. Of these, only a handful survived the sinking of the ship.

Boiler rooms
Titanic's six boiler rooms housed the 29 boilers needed to power the colossal ship, venting steam through three of the four funnels.

WHO'S WHO?

CAPTAIN SMITH 1850-1912

Edward John Smith began working for White Star Line in 1880 and it became tradition for him to skipper each of the White Star Line's new ships on their maiden voyage. He captained the Olympic in 1911 before Titanic in 1912. Despite being a bit of a maverick behind the wheel, he's often lauded as a hero after going down with the ship.

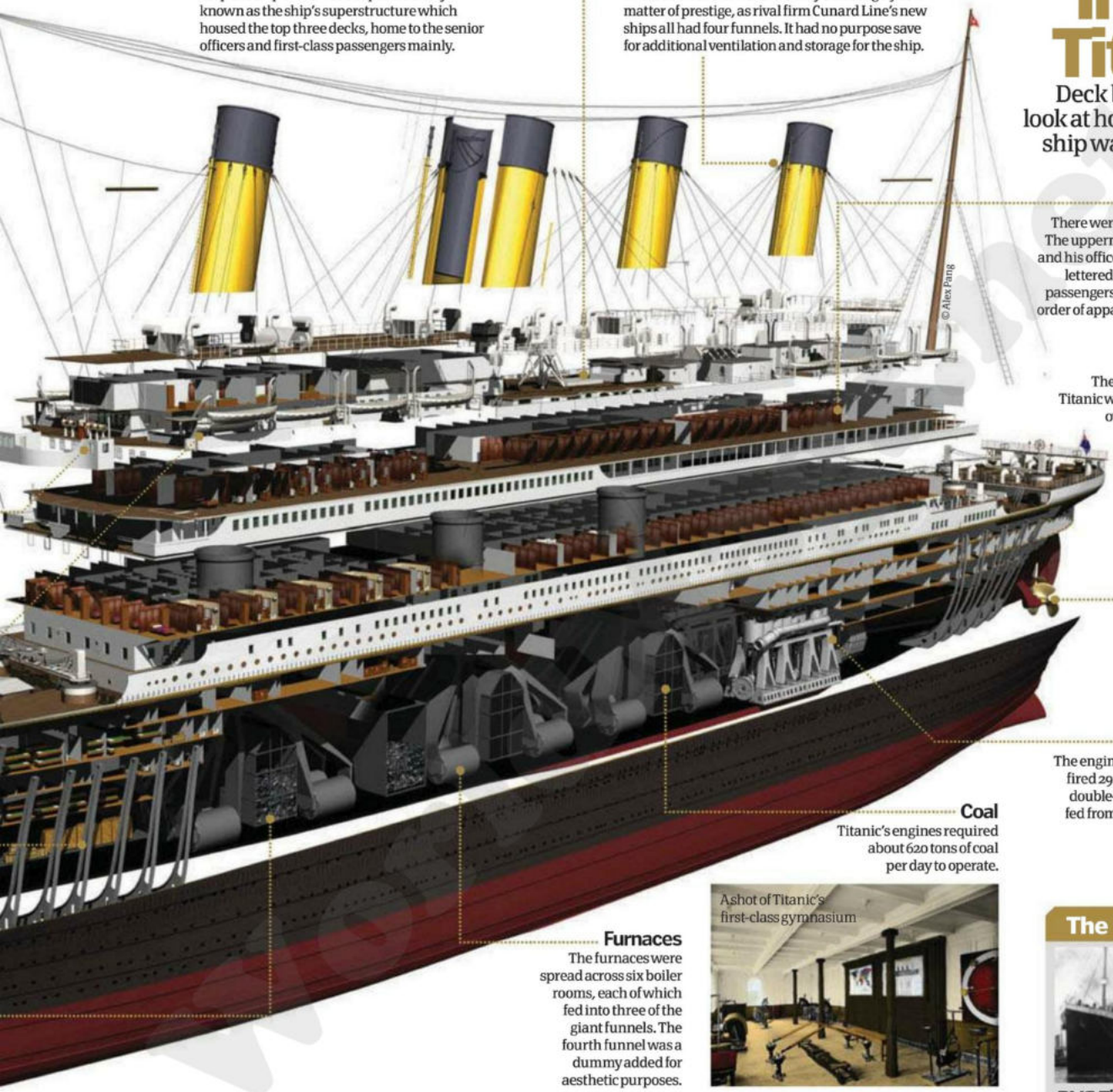
DID YOU KNOW? *RMS stands for Royal Mail Ship, an acronym used to designate vessels licensed to carry post by Royal Mail*

Inside Titanic

Deck by deck, take a look at how this mighty ship was put together

Superstructure
Atop the ship's hull was a separate entity known as the ship's superstructure which housed the top three decks, home to the senior officers and first-class passengers mainly.

Fourth funnel
The fourth funnel was a dummy built largely as a matter of prestige, as rival firm Cunard Line's new ships all had four funnels. It had no purpose save for additional ventilation and storage for the ship.



Decks
There were eight decks on Titanic. The uppermost housed the captain and his officers, and the next seven – lettered A through to G – housed passengers and crew in decreasing order of apparent social importance.

Horsepower
The entire engine system of Titanic was capable of producing over 33,500kW (45,000hp).

Engines
The engines had 159 furnaces that fired 29 boilers. 24 of these were double-ended, so they could be fed from both sides, and the rest were single-ended.

Coal
Titanic's engines required about 620 tons of coal per day to operate.

Furnaces
The furnaces were spread across six boiler rooms, each of which fed into three of the giant funnels. The fourth funnel was a dummy added for aesthetic purposes.

A shot of Titanic's first-class gymnasium

development that would later prove crucial in the sinking of Titanic, the various steel plates of the vessel's hull were riveted together, as welding techniques were not yet sufficient in the early-20th century to hold together a ship of Titanic's magnitude.

One of Titanic's most innovative features, and also possibly somewhat responsible for its sinking, was its engines. Its two twin four-cylinder engines each measured almost 12.2 metres (40 feet), the largest of their kind. These powered two three-blade propellers – one port and one starboard – at the stern. The propellers were a hefty 7.2 metres (23.5 feet) wide and rotated in opposite directions, 75 times per minute, to lessen vibrations. An additional third propeller was positioned between the two main propellers for added efficiency. It was smaller than the other two and used steam from their engines to rotate up to twice as fast. However, unlike the other two it was unable to rotate backwards, which would ultimately prove detrimental when Titanic came face to face with an iceberg. Steering of the ship was largely handled by a mammoth, if somewhat cumbersome, 100-ton rudder.

Titanic was 11 storeys tall and as long as six city blocks. Its interior decks, especially the lower ones encased by the hull, were a maze of narrow passages (known as alleyways) and ▶

The statistics...

RMS Titanic

Class: Olympic-class ocean-liner
Weight: 46,328 tons
Length: 269.1m (882.9ft)
Width: 28m (92ft)
Height (to top of funnels): 53.3m (175ft)
Top speed: 24 knots (44km/h; 28mph)
Decks: 8
Passenger capacity: 2,439
Crew capacity: 900

"The impact with the iceberg produced a tear on the hull of Titanic more than 90 metres (300 feet) in length"

How Titanic foundered

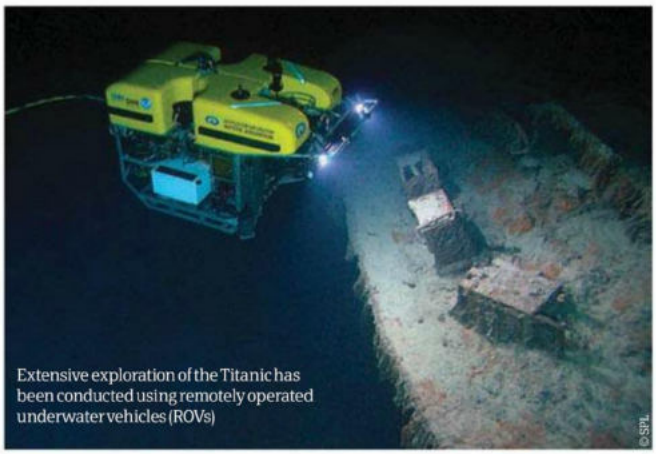
Map of the voyage

doors that only a few officers on board were able to competently navigate. Indeed, Second Officer Charles Lightoller recounted later that it took him 14 days aboard to be able to learn how to navigate from one end of the ship to the other. Considering Titanic sank just four days after it set off, with all the passengers on board never having set foot on the ship before, the complexity of its design brought obvious difficulties at the time of its sinking. Very few passengers in the steerage class were able to navigate their way successfully to the upper decks when Titanic began to sink. The story of how it sank though is a combination of poor design, bad luck and misdirection.

At 11.40pm on 11 April 1912, lookout Frederick Fleet spotted an iceberg directly ahead of Titanic and telephoned the bridge. Quartermaster Robert Hichens was ordered to change course. However, the turning procedure took up to 30 seconds owing to several factors, including the inability of the ship's third propeller to rotate backwards and the attempted deceleration of the ship, resulting in Titanic striking a glancing blow on the iceberg. Indeed, it may even have been better for the ship to speed up rather than attempt to slow down, as doing the latter lessened its turning angle. It is estimated that if Titanic had maintained its speed, it would have avoided the fatal iceberg by several metres.

The impact with the iceberg produced a tear on the hull of Titanic more than 90 metres (300 feet) in length above the keel. The iron rivets used to keep the steel plates of the ship together were brittle and prone to snapping, while the plates themselves were weaker than modern steel due to impurities, meaning that they easily buckled under pressure from the iceberg. However, save for a loud bang near the point of impact there was little evidence of a collision throughout the majority of the ship apart from a slight shudder.

Water poured into the tear at a rate of about seven tons a second, flooding the Number 6 boiler room. Engineering staff worked to extinguish the furnaces and vent the boilers before they exploded upon contact with the icy cold water. The lower decks of Titanic were divided into 16 compartments,


Extensive exploration of the Titanic has been conducted using remotely operated underwater vehicles (ROVs)

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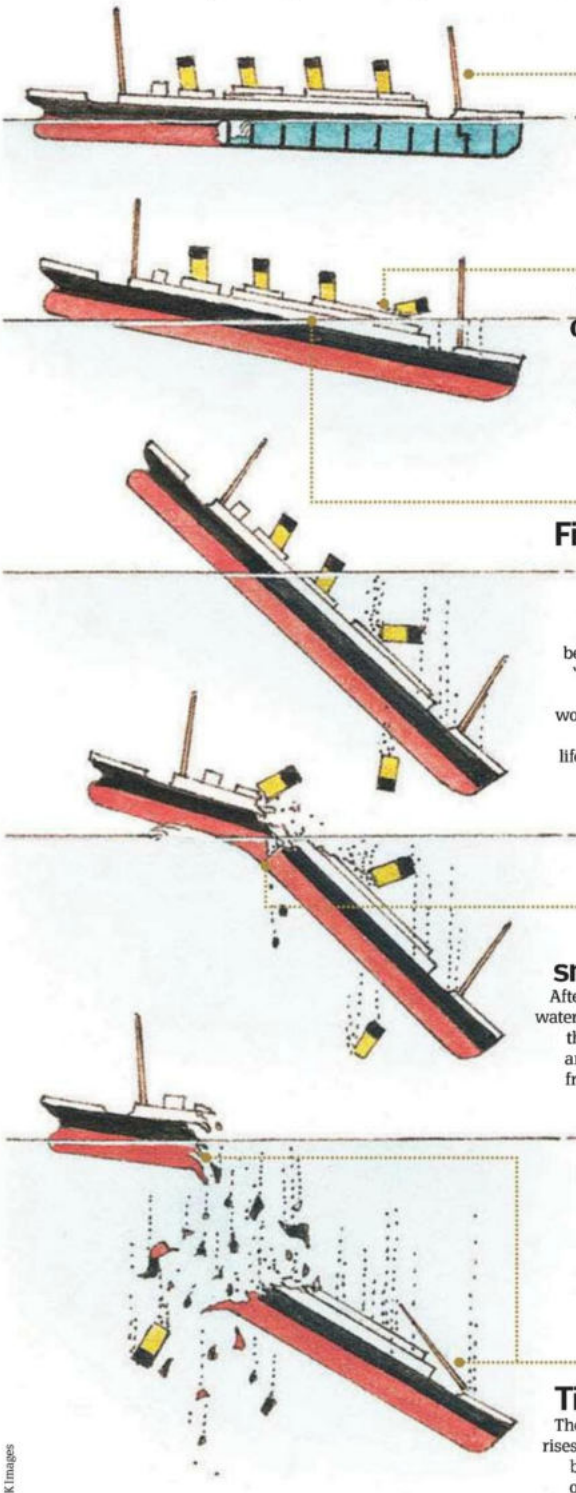
Stages of sinking

In just over two and a half hours Titanic went from ship-shape to shipwreck



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5 TOP FACTS MARITIME DISASTERS

1 SS Sultana
The steamboat SS Sultana exploded and sank on 27 April 1865. Up to 1,800 of the 2,300 passengers on board died, the largest loss of life from a maritime disaster in US history.

2 MV Doña Paz
Up to 4,375 people died when the Philippine-registered passenger ferries MV Doña Paz and MT Vector collided on 20 December 1987, the deadliest peacetime ferry disaster.

3 Wilhelm Gustloff
On 30 January 1945, during WWII, German ship Wilhelm Gustloff was sunk by a Soviet Navy sub. Up to 9,400 died in the greatest ever loss of life in a maritime disaster.

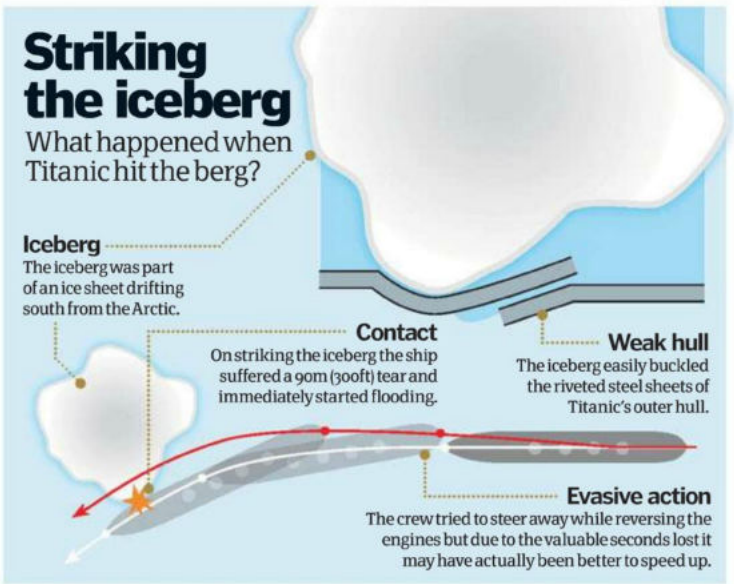
4 Yamato
This Japanese warship was the largest battleship ever constructed. It was sunk on 7 April 1945 by US torpedo planes. Of the 2,778-man crew only 280 survived.

5 Costa Concordia
Costa Concordia ran aground on 13 January 2012 near the Isola del Giglio. More than 17 people are thought to have died when the ship was taken on an inappropriate course.

DID YOU KNOW? *Captain Smith narrowly averted crashing Titanic into the SS New York at the very start of its voyage*

Striking the iceberg

What happened when Titanic hit the berg?




One of Titanic's lifeboats carrying far fewer passengers than it was designed to

separated by bulkheads running the width of the ship. However, the bulkheads did not rise to the very top of the vessel, meaning that as water flooded each compartment it spilled into adjacent ones. Five compartments were breached by the iceberg; Titanic could only stay afloat with four flooded.

Due to the uneven rate of flooding, the ship listed five degrees starboard just minutes after the collision. After 45 minutes, over 13,000 tons of water had been taken on board. The bilge pumps could only eject about 1,700 tons per hour, making it readily apparent that Titanic was doomed. The forward part of the ship gradually began to sink lower into the sea. Two hours on, the vessel was tilted forwards at an angle of ten degrees. This greatly increased the rate of flooding and, by 2.18am, the stress on the keel became too great, resulting in the ship snapping in two. The front half descended slowly to the bottom of the Atlantic but the back end rose to a vertical position in the water before crashing to the seabed at up to 48 kilometres (30 miles) per hour.

There were 2,206 passengers and crew on board Titanic. Of these, only 711 survived, despite the 20 lifeboats having a combined capacity of 1,178. There are several factors to blame, which include an inadequate number of lifeboats (although above the legal number for ships in 1912), poorly executed orders, lack of a ship-wide announcement system and inadequate information given to passengers. Indeed, up until the final hour many on board were convinced the ship would not sink. The high-profile sinking of Titanic sparked a complete overhaul of sailing safety measures, and a raft of changes were put in place to prevent such a disaster from occurring again. With the sinking of the Costa Concordia in January 2012, however, it's clear that, even 100 years after this great disaster, there are still many lessons to be learned.

Interview Greg Ward

We speak to the author of The Rough Guide To The Titanic to find out his thoughts on one of the greatest peacetime maritime disasters in history

How It Works: How did you become so interested in Titanic?
Greg Ward: I've written lots of books over the years, including history books, but my interest in Titanic came from my mother-in-law. She's a film professor and she organised a conference for James Cameron's *Titanic* movie in 1999 that I went along to, and after that I got very interested in Titanic. The most interesting for me is why Titanic looms so large in popular culture, and why the anniversary is such a big deal. It's a fascinating thing to consider, and it sort of goes beyond the ship itself.

HIW: What was the biggest challenge when researching?
GW: There's been so much written about Titanic, so there's a basic story out there. However, I came with a fairly fresh view on it so I didn't have any preconceived ideas about the story. One thing you find is that so many people have a particular axe to grind, and there are all sorts of controversies and issues and debates that people like to take sides on and run with. The challenge was to realise there were so many different stories with varying information that you just had to accept there are some things we don't know about the night Titanic sank. It's a disaster that happened in the middle of the night in the North Atlantic out of sight of the world.

HIW: What do you feel were the main factors that led to Titanic hitting an iceberg?
GW: There were two big inquiries after the event, first in America and then Britain, which overlap with people who testified in both. They came to a similar conclusion, which the British one put fairly succinctly in that Titanic hit the iceberg because it was going too fast and couldn't get out of the way, as obvious as it sounds. They said the captain, E J Smith, was pushing the ship too hard. Nobody at the time realised that was such a danger, and now anyone who caused the same event would be guilty of gross negligence. I think it's fascinating that the biggest and most advanced ship on the sea should be the one to hit an iceberg.

HIW: Why is the story of Titanic blurred in fact and fiction?
GW: Most of the survivors did not reach New York for three days after the disaster. At that point everybody in the world had heard Titanic had sunk, but there had been no details of what actually happened. The newspapers had to fill the news so they basically made things up or went with what they assumed must have happened. Other stories were based on small anecdotes or isolated incidents. For example, the story of the band playing *Nearer, My God, To Thee* as the ship went down came from just one particular survivor who said it was the last thing she saw, but she left on the first lifeboat 90 minutes before the ship sank. It's unlikely they kept playing till the bitter end as is often reported.

HIW: Have we learned any lessons from the Titanic?
GW: I watched a documentary about the sinking of the Costa Concordia recently, and there was footage of this stewardess saying everything is all right and there's no need for alarm while the ship was going down, and that passengers should return to their cabins. It's quite chilling to see that, even after Titanic, people are still not kept informed during such a disaster. The instinctive reaction of the Titanic authorities was that it's best to prevent panic, and it's scary to think it's exactly the same 100 years on.

The Rough Guide To The Titanic is available for £9.99/$14.99 from **www.roughguides.com**.

"Today, articles are commonly stamped via hydraulic presses"

Hallmarks explained

Why are precious metals often impressed with these small icons and how are they applied?

Hallmarks are an official series of icons and numbers which are imprinted on to a variety of precious metals, such as gold and silver, to denote their purity and fineness. Any hallmark is determined and applied today by an assay office, an institution that specialises in assessing a metal's quality by formal metal testing.

Traditionally, however, hallmarks were administered by guilds, which were industrial groups set up to preserve the standards of a particular craft. This practice began in England in 1327, when King Edward III dictated that all silver articles must meet a purity rating of 92.5 per cent and delegated its enforcement to the Worshipful Company of Goldsmiths.

Due to the soft nature of assayed metals, the application of a hallmark is achieved via stamp pressing, which traditionally was executed by hand. Today, articles are commonly stamped with their hallmark via hydraulic presses, however laser marking is an emerging technology used for smaller, more awkward pieces.

5 TOP FACTS
POMPEII

Widespread
1 The 79 CE eruption of Mount Vesuvius did not just destroy Pompeii but also the city of Herculaneum, as well as severely affecting the other nearby city of Stabiae.

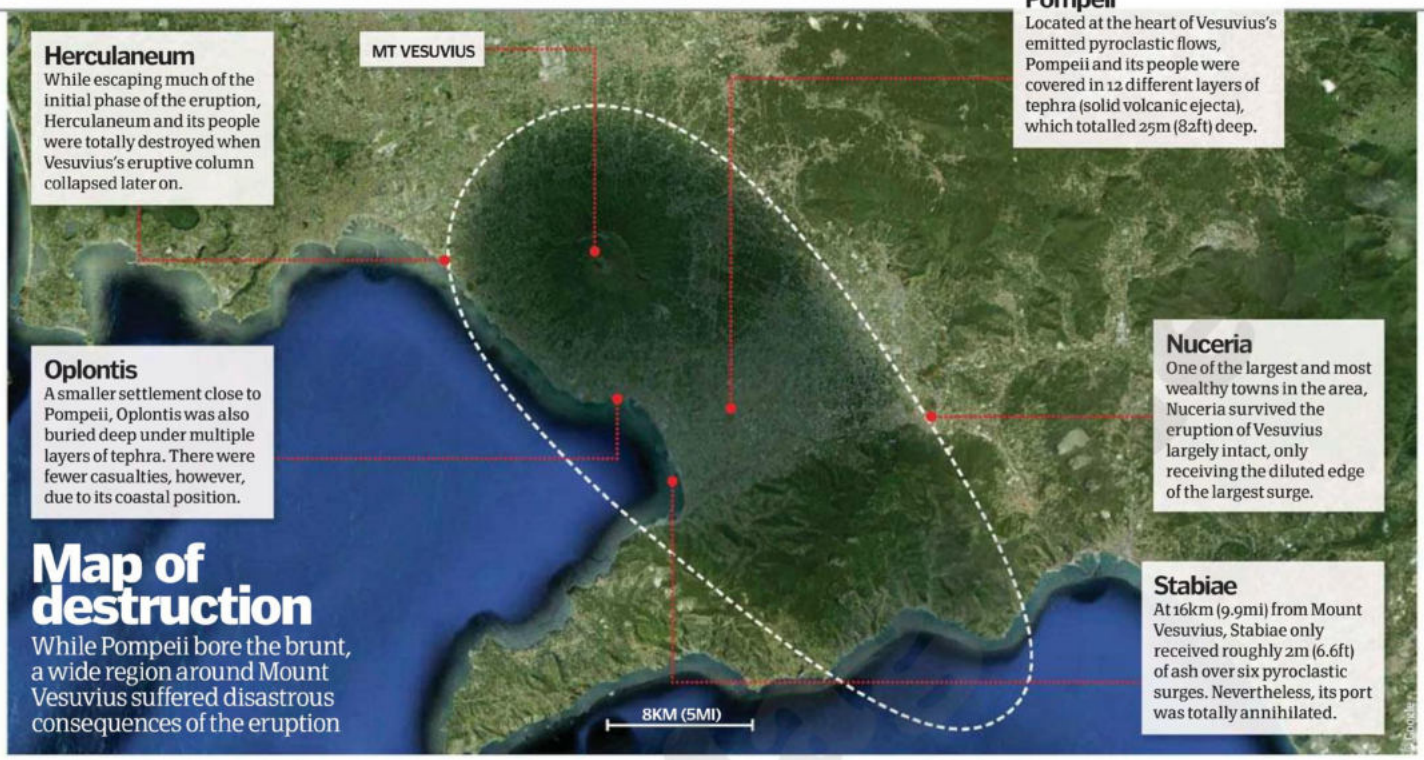
Hothead
2 Vesuvius emitted clouds of stones, ash and fumes to a height of 32 kilometres (20 miles) and spewed molten rock and pumice at a rate of 1.5 million tons per second.

Pliny
3 According to Roman historian Pliny the Younger, the ash from Mount Vesuvius blocked out the Sun, stating that "the darkness was darker and thicker than any night."

Rediscovered
4 Pompeii was rediscovered in 1748 by Spanish military engineer Rocque Joaquin de Alcubierre, who excavated many intact buildings and wall paintings.

Silent
5 Pompeii has not erupted since 1944, leading many scientists to predict it will do so again in the near future and that the longer it remains silent, the worse it will be.

DID YOU KNOW? *Today, Pompeii is a UNESCO World Heritage Site that anyone can visit*



The destruction of Pompeii

When Mount Vesuvius erupted in 79 CE, it wiped the city of Pompeii off the face of the planet, burying both it and its citizens under tons of volcanic fallout

Pompeii was a medium-sized Roman city in the Italian region of Campania. In 79 CE, however, it was completely destroyed in the eruption of nearby Mount Vesuvius, a stratovolcano located close to the city of Naples.

The destruction of Pompeii (and other cities; see 'Map of destruction') was caused according to stratigraphic studies in two main phases. The first phase was a Plinian eruption, which is typified by a colossal ejection of gas and volcanic ash high into the stratosphere. This phase lasted roughly 20 hours and produced a rain of pumice in a southwards-reaching cone that stretched for over 32 kilometres (20 miles).

The second – and for the people of Pompeii, even more deadly – phase was a Peléan eruption, which consisted of a number of vast pyroclastic flows. These flows were fast-moving currents of superheated gas (at roughly 1,000 degrees Celsius/1,800 degrees Fahrenheit) and rock that rapidly dispersed at ground level into the surrounding area. The combination of both these phases led to the burning and asphyxiation of all life that stood in harm's way.

In addition, the eruption caused a small tsunami in the nearby Bay of Naples, rendering escape attempts by boat impossible, and a series of tremors that aided the destruction of dwellings and temples.

Today, over a thousand casts have been made from impressions of bodies trapped in Vesuvius's ash and flow deposits discovered in and around Pompeii, along with various other scattered remains. Out of the total found, 38 per cent were discovered in ash fall, with the remaining 62 per cent found in surge deposits. Unfortunately, due to a lack of official documentation from the time, what percentage these represent of Pompeii's total population is unknown.

Since the eruption of 79 CE, Mount Vesuvius has erupted more than 30 times, the last occurring in March 1944. Despite this, the area surrounding Mount Vesuvius continues to be lived in by many Italians, with the entire region in its immediate vicinity colonised. To combat the potential for disaster, the Italian government foresees the need for an emergency evacuation of over 600,000 people and has marked a 'Red Zone' for those areas that would be most severely affected.


© Pastorius
Mount Vesuvius as seen today from above


A body cast of a victim from Pompeii. This person was in a crouched position holding his hands over his nose and mouth when he died
©SPL

"They collected 2,109 animals and fish, of which 401 had never been documented before"

The race to the South Pole

How It Works turns a spotlight on Captain Scott's ill-fated expedition to Antarctica

Captain Robert Falcon Scott's Terra Nova expedition was the equivalent to a mission to Mars today. Antarctica was just as alien, deadly and fascinating as the Red Planet, and it needed a great deal of preparation and planning for anyone to even contemplate making it to the South Pole.

To reach the Antarctic, Scott bought the Terra Nova, an old whaling ship that was reinforced with 2.1-metre (seven-foot) oak beams from bow to stern. Transport on the ice consisted of three motorised sledges and 44 normal sledges. They brought 19 ponies and 33 dogs with them to pull the sledges, though Scott always planned to man-haul these on the final leg of the journey.

To deal with the weather that can range from -30 degrees Celsius (-22 degrees Fahrenheit) in the summer to -60 degrees Celsius (-76 degrees Fahrenheit) in the winter, they wore wool and fur-lined waterproof clothing, mittens and finnesko (reindeer skin) boots. Tinted goggles were also used to help prevent snow blindness.

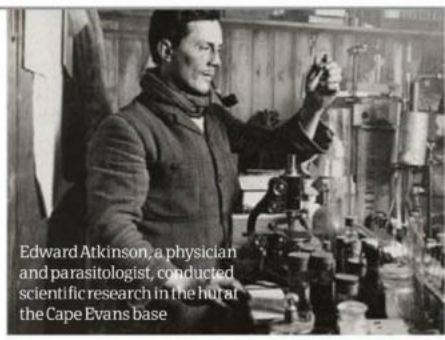
Away from base camp, paraffin-fuelled Primus stoves were employed to heat the explorers' meals and drinks. Much of their diet comprised a mixture of mincemeat and oil called pemmican; this was combined with melted snow to make a stew called hoosh. Daily rations also included hard, high-protein biscuits, tea and cocoa. They slept in four-man tents that consisted of four bamboo corner poles covered with a lined canvas fabric.

Throughout the journey of the Terra Nova, observations were made of the marine biology, meteorology and currents, tides, salinity and the temperature of the sea. On reaching Antarctica, two geological journeys were carried out to explore the geology of the Western Mountains, and a three-man team made a special study of the emperor penguin.

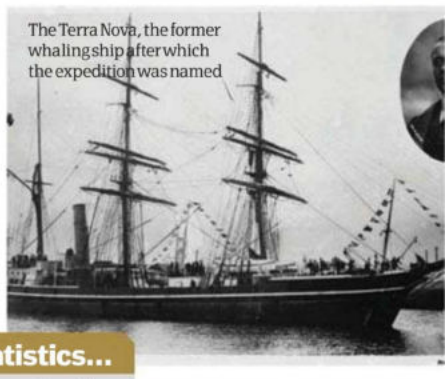
They collected 2,109 animals and fish, of which 401 had never been documented before, along with samples of volcanic rock and fossilised plants. More meteorological data was collected and they carried out hydrographic measurements of both land and sea.

The main party headed by Scott spent their time laying depots of supplies and food to support the journey to the South Pole, which they eventually reached on 17 January 1912. Pipped to the post by Norwegian explorer Roald Amundsen, Scott's team died from a combination of dehydration, hypothermia and scurvy on their return to base. Their bodies were found on 12 November 1912.

Although ending in tragedy, Scott and his men were hailed as patriotic heroes who fought and lost against great odds. They certainly left a legacy of scientific research that still helps us today to understand the many mysteries of the Antarctic.



Edward Atkinson, a physician and parasitologist, conducted scientific research in the hut at the Cape Evans base



The Terra Nova, the former whaling ship after which the expedition was named

Oates, who was responsible for the horses, often argued ponies were not suited to the icy terrain

The final five

The statistics...

Robert Falcon Scott

Lived: 6 June 1868-29 March 1912

Info: Scott, along with Ernest Shackleton and Edward Wilson, got within 850 kilometres (530 miles) of the Pole during his first 1901-1904 Discovery expedition. Afterwards, he and Shackleton became rivals. Scott had an autocratic style of leadership, yet he was shy. He also suffered from long periods of depression.

The statistics...

Lawrence Oates

Lived: 17 March 1880-16 March 1912

Info: Oates contributed £1,000 to the expedition fund and was in charge of the ponies that pulled the sledges that lay down the food depots and supported the first leg of the polar journey. He was highly critical of Scott's leadership skills. Famous for sacrificing himself so that the team could go on without him.

The statistics...

Henry Bowers

Lived: 29 July 1883-29 March 1912

Info: Bowers was a very tough and hard-working character, who was nicknamed 'Birdie' due to his beak-like nose. He took responsibility for organising food supplies, loading the sledges, organising the stores and planning the logistics for the march to the Pole.

5 TOP FACTS
POLAR EXPLORERS

James Clark Ross
1 Commanding two vessels, HMS Erebus and HMS Terror, Ross charted the Antarctic coastline from 1839-43. He discovered the Antarctic is a continent and set a record for sailing so far south.

Roald Amundsen
2 Amundsen's team was regarded as more skilful on skis, and benefited from using dog sledges. Amundsen was also the first undisputed man to reach the North Pole.

Ernest Henry Shackleton
3 Shackleton was part of Scott's 1901-04 Discovery expedition. He went on to lead his own 1907-1909 Nimrod expedition, which discovered the Beardmore Glacier.

Richard E Byrd
4 Admiral Byrd was the first person to fly to the South Pole. Using a Ford Trimotor aircraft he and three crew flew from his Little America base on 28 November 1929.

Carl Anton Larsen
5 Larsen led the first Norwegian Antarctic expedition from 1892-94. In 1893, he was the first to use skis on Antarctica where he discovered the Larsen Ice Shelf.

DID YOU KNOW? *Scott's last journal entry on 29 March 1912 talks of his companions' 'hardihood, endurance and courage'*

Inside Scott's hut

The prefabricated hut only took two weeks to build after Scott landed at Cape Evans on 4 January 1911. It measured 7.6 metres (25 feet) wide, 15.2 metres (50 feet) long and 2.7 metres (nine feet) high.

The wood board walls were insulated with ruberoid and shredded seaweed inside jute lining bags, and it was heated by a seal blubber-fuelled stove. It featured living quarters, bunk beds and laboratories. Stables were built to the north side and a storeroom was added to the south of the hut.

It included a photographic darkroom and the laboratories were filled with radio and chemical equipment, microscopes for examining biological samples, dissecting tables and a range of thermometers and meteorological recording devices including a Dynes anemometer that measured wind velocity. The scientists in the team regularly lectured on their research to the rest of the expedition members.

Life in the hut was relatively comfortable. Acetylene generators provided artificial light, while a pianola (autopiano) and a gramophone player entertained them during their limited leisure time. Cooked food was plentiful and varied, and the heating pipes from the stove kept them warm; all a stark contrast to conditions outside the hut.


The hut at Cape Evans played host to 25 men

Learn more
For an in-depth account of the full expedition, take a look at *Scott Of The Antarctic: We Shall Die Like Gentlemen* by Sue Blackhall.

The race is on...

Scott was not aware he was 'racing' to the South Pole until he received a telegram from Roald Amundsen on 12 October 1910, which read: 'Beg to inform you Fram proceeding Antarctic – Amundsen'. This made Scott even more determined to claim the South Pole for Britain.

14 December 1911
FIRST ARRIVAL
Roald Amundsen arrives at the South Pole with Olav Bjaaland, Helmer Hanssen, Sverre Hassel and Oscar Wisting. They stay on the plateau for three days and name it after King Haakon VII.

16 January 1912
FLAG
Scott's five-man team see Amundsen's flag in the distance and realise he has beaten them. They arrive at the South Pole the next day.

3 January 1912
POLAR PLATEAU
Scott traverses the Polar Plateau, and selects the team members who will travel the remaining 269 kilometres (167 miles) to the Pole.

4 December 1911
BEARDMORE GLACIER
Scott's expedition is hit by a blizzard. The ponies are shot and the dogs sent back to base.

17 February 1912
RETURN
At the bottom of the Beardmore Glacier, Edgar Evans dies after suffering severe frostbite. Scott's team encounters extreme weather.

24 October 1911
SCOTT'S POLAR JOURNEY
16 men using motor, dog and pony sledges start the journey to the Pole.

16 March 1912
SACRIFICE
Captain Oates leaves the expedition tent to a certain death, parting with the famous words, "I am just going outside and may be some time."

14 January 1911
FRAMHEIM
The Fram, the ship carrying Amundsen, lands at Framheim, in the Bay of Whales where their base is established.

4 January 1911
ARRIVAL
Terra Nova lands at the 'Skuary', McMurdo Sound, Ross Island, which they rename Cape Evans.

29 March 1912
THE END
In the midst of a blizzard, suffering temperatures of -40 degrees Celsius (-40 degrees Fahrenheit) with no supplies, Scott makes his last diary entry. Bowers, Scott and Wilson die in their tent only 18 kilometres (11 miles) from One Ton Depot.

The statistics...
Edgar Evans

Lived: 7 March 1876-17 February 1912

Info: Petty officer Evans was a Welshman with a reputation for drinking and womanising. Scott nonetheless admired him for his strength and resourcefulness. He was responsible for loading the sledges and looking after the equipment. Returning from the Pole his mental and physical condition rapidly deteriorated.

The statistics...
Edward Wilson

Lived: 23 July 1872-29 March 1912

Info: The ever-helpful Wilson was the chief of scientific staff. He was a physician and zoologist who had made a special study of penguins, whales and seals in the Antarctic. He was also an accomplished watercolour artist.

BRAIN DUMP

Because enquiring minds want to know...

Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

HOW IT WORKS EXPERTS

ROYAL BC MUSEUM

Dr Richard Hebda
Curator of Botany and Earth History

Richard studies fossilised plant remains and the information they provide on evolution and the history of the landscape, plant geography and climate.

Dr Rob Cannings
Curator of Entomology

Rob is crazy about all insects but his favourites are dragonflies and robber flies, the stars of several of his books. He was also a biologist in BC Parks and a lecturer and curator at the University of BC.

Dr Gavin Hanke
Curator of Vertebrate Zoology

Gavin's degrees are in fish biology, biogeography and evolutionary biology. He was the zoologist at the Manitoba Museum, but now studies fossil fishes, native living fishes and exotic species in BC.

Dr Ken Marr
Curator of Botany

Ken studies the flora and biogeography of northern BC, especially alpine plants, and also enjoys ethnobotany. Before coming to the Royal BC Museum, he spent time in China researching the domestication of Asian melons.

Is there a difference between brown and black bears?

Martin Conley

Kermode bears are blond black bears (ursus americanus) found along British Columbia's coast. Kermode bears can produce black young if they mate with a black black bear, and black black bears can produce white young if both adults possess recessive genes for 'blond' colouration. Black bears can also have beige, cinnamon and blue-grey colouration. Grizzly, or brown, bears (ursus arctos), meanwhile, have a distinct shoulder hump, dish-shaped face and long claws. Black bears are smaller, lack the shoulder hump, have short claws and an elongate dog-like face. Grizzly bears occasionally mate with polar bears – producing hybrids nicknamed 'pizzly' or 'grolar' bears – but not with black bears.

Dr Gavin Hanke, curator of Vertebrate Zoology

© Jim Chapman

Just like humans, a bear's colouring all comes down to its parents

What are neutrinos?
Find out on page 85

Which is Canada's deepest lake?

William Dennis

Great Slave Lake in Canada's Northwest Territories is our deepest lake, reaching about 614 metres (2,000 feet) in depth. It is the ninth deepest lake in the world and was likely formed as a result of the scouring of the great continental Laurentide Ice Sheet.

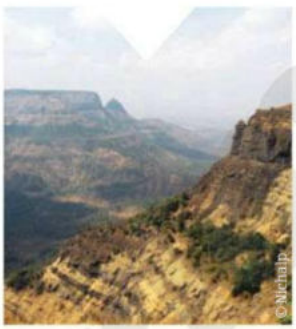
Dr Richard Hebda, curator of Botany and Earth History

What killed off the dinosaurs?

Rachael George

An asteroid impact at Chicxulub in the Yucatán Peninsula of Mexico led to major climatic changes, as a result of the huge volume of crustal debris (dust) spewed into the atmosphere for several years. Some scientists say another impact off India (now the Shiva Crater) had a role to play, while others also blame massive volcanic activity in India's Deccan Traps (right).

Dr Richard Hebda, curator of Botany and Earth History



How do red and grey squirrels differ?

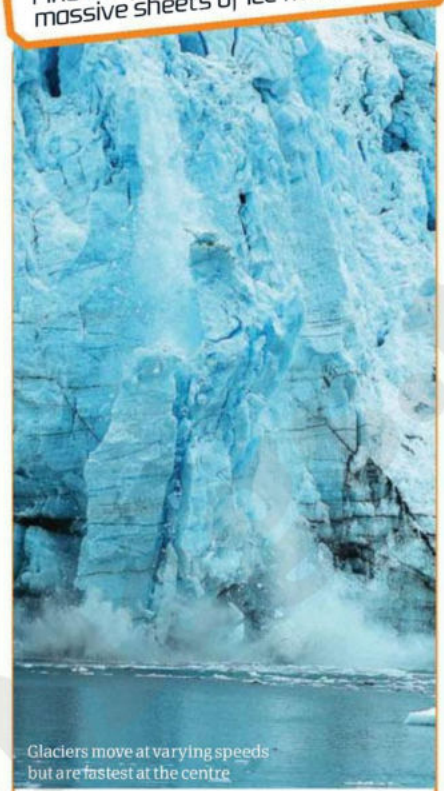
Dana Wolcott

There are two red squirrel species in the northern hemisphere. North American red squirrels are small and have a red-brown back, a black side stripe and white belly, while Eurasian red squirrels are large with a red to grey grizzled coat and white belly, or are melanistic (black). The grey squirrel also is large and is a well-known invasive species. Grey squirrels are either a grey-brown grizzled colour with a light belly or melanistic. The two species can also differ in bone and tooth structure, but these features are difficult to examine in live animals!

Dr Gavin Hanke, curator of Vertebrate Zoology

INSTANT GENIUS

Find out precisely how these massive sheets of ice move



Glaciers move at varying speeds but are fastest at the centre

THE EXPERT

WHO: Dr Richard Hebda

As well as curating the Botany and Earth History exhibits at the RBCM, Richard also supervises graduate students in Biology and Earth Sciences at the University of Victoria.

How quickly do glaciers travel?

Jacqueline Brown

The speed of glaciers varies greatly depending on ice thickness, temperature, slope, snowfall and the presence of meltwater at the contact point between the ice and the land underneath; indeed, some glaciers do not move at all. Many move at a rate between zero and about half a kilometre (0.3 miles) per year. The fastest moving glacier is in Greenland, rushing forward at 12.6 kilometres (7.8 miles) per year. The middle of a glacier moves much more quickly than its edges, which are held back by friction with the surrounding land. Large objects frozen in the ice may get stretched apart because of this differing rate of movement.

ROYAL BC MUSEUM

What's on?

Dinosaurs: Ancient Fossils, New Discoveries

WHAT: Bioengineering software and CT scans – as well as new ideas and discoveries – are helping to reinterpret dinosaur mysteries, including why, or whether, they became extinct. From the American Museum of Natural History, this exhibition highlights cutting-edge research by palaeontologists and other leading scientists.
WHERE: Royal BC Museum, Victoria, BC, Canada
WHEN: 17 May-16 September, 10am-5pm
PRICE: With admission/membership

Night at the Museum Family Sleepover

WHAT: After everyone has gone home and the Museum has closed its doors for the night, we invite families to join us in the Dinosaurs exhibition for late-night flashlight tours, pancake breakfast, games, stories, activities and a little morning exercise – to work off those pancakes!
WHERE: Royal BC Museum, Victoria, BC, Canada
WHEN: 25-26 May, 6.30pm-9am
PRICE: CA$75 per person. Early registration and ten per cent discount available for members

Junior Palaeontologists and Dino Diggers

WHAT: Want to be a famous dinosaur hunter? Join Dr Philip Currie, one of the world's best-known palaeontologists, to learn about his discoveries and find out if you have what it takes to dig up history.
WHERE: Newcombe Conference

BRAIN DUMP

Because enquiring minds want to know...

How do you cut diamonds?
Find out on page 86

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

Dandelions are some of the most successful plants in the world having spread to every continent on the planet

ROYAL BC MUSEUM

What's on?

Hall, Royal BC Museum, Victoria, BC, Canada
WHEN: 26 May, 1-2pm
PRICE: CA$5 per person, ten per cent member discount

Feature presentation: Dinosaurs with Phil Currie

WHAT: Join dinosaur scientist Dr Philip Currie as he highlights recent advances in our understanding of how dinosaurs looked, moved, behaved and died. Dr Currie is a Canada research chair at the University of Alberta in the Department of Biological Sciences and former curator of Dinosaurs at the Royal Tyrrell Museum of Palaeontology in Alberta.
WHERE: IMAX Theatre, Royal BC Museum, Victoria, BC, Canada
WHEN: 27 May, 10.30am-12pm
PRICE: CA$15. Early registration and ten per cent discount for members

2011 Wildlife Photographer of the Year

WHAT: The world's best images, from more than 41,000 entries. This is the first and perhaps only stop in North America for the 108 winning images in a contest run by *BBC Wildlife Magazine* and the Natural History Museum, London. Each of the huge images – of plants, animals and wild places – is perfectly backlit.

© Hui Yu Kim

Which is the smartest bird?
Find out on page 87

Roughly how many seeds do dandelions generate?

Ralph Sharp

The common dandelion (taraxacum officinale) originated in Europe, but has spread to every continent, from the Arctic to the tropics. Each plant produces a single seed head that bears 40-100 or more seeds. This species and its relatives are quite variable in morphology, leading to much disagreement about how many species exist and how to distinguish among them. Some taxonomists consider there to be 60 species in the taraxacum genus, while others consider the number to be closer to 2,000!

Dr Ken Marr, curator of Botany

© Brian Gratwicke

Do grey tree frogs actually live in trees?

Declan Butcher

Grey tree frogs – including the Cope's grey tree frog (above) – do frequent trees and may live far from ponds and lakes. These amphibians are camouflaged to look like lichen-covered bark and blend really well with arboreal surroundings. There are several reasons tree frogs branched out from their terrestrial ancestors, such as fewer competitors for insect prey and perhaps fewer predators (larger frogs and several snakes are known to eat small frogs). Unlike many tropical species, grey tree frogs return to the ground each spring to lay eggs in ponds and ditches – they are far easier to find and catch at this time.

Dr Gavin Hanke, curator of Vertebrate Zoology

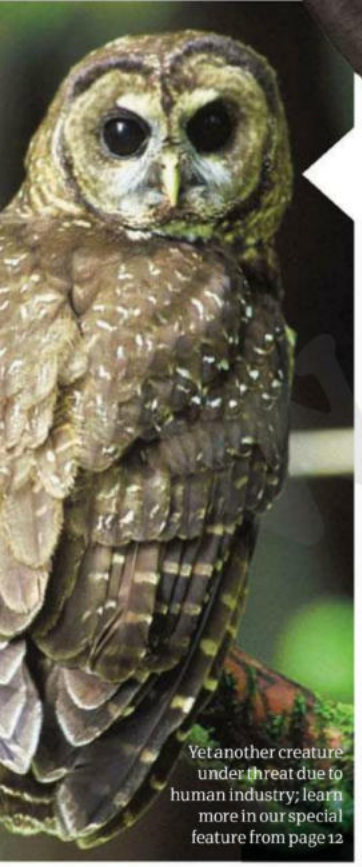
Were hadrosaurs larger than a T-rex?

Katie Kaur

Hadrosaurs, commonly called duck-billed dinosaurs, were large plant eaters mostly about seven to ten metres (23-33 feet) long with an average weight of about 3,000 kilograms (6,614 pounds). Most hadrosaurs were likely smaller than tyrannosaurus rex, but perhaps the largest could have reached a similar size. T-rex individuals were as big as 12.8 metres (45 feet) long and four metres (13 feet) high at the hip; they weighed in at almost seven tons.

Dr Richard Hebda, curator of Botany and Earth History

© Steveoc 86



Yet another creature under threat due to human industry; learn more in our special feature from page 12

Which is the most endangered species native to British Columbia?

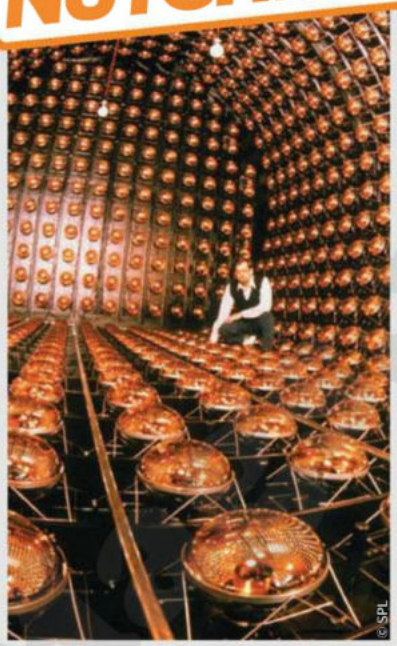
Alicia Lamb

Spotted owls (strix occidentalis) live in old-growth forests of western North America from southwestern BC through to Mexico. In the US, the species is considered threatened, while in Canada it is designated endangered. In BC, about six pairs remain in the wild, a tiny remnant of the estimated historic population of 500 pairs. Much of their habitat is gone – logged and developed. Controversy between environmentalists and loggers over protection of these forests has raged for years. Biologists also fear that the more aggressive barred owl, whose populations are increasing in the region, is pushing the spotted owl out of its disappearing habitat.

Dr Rob Cannings, curator of Entomology

EXPLAINING COMPLEX TOPICS SIMPLY

IN A NUTSHELL



© SPL

WHAT ARE NEUTRINOS?

Katherine Cooke

Neutrinos are elementary subatomic particles with no electric charge, almost no mass and half a unit of spin. As neutrinos are electrically neutral they are not affected by electromagnetic forces and, as a result, they are differentiated from charged particles such as protons and electrons. In contrast, neutrinos are only affected by the weak force which underlies certain processes of radioactive decay.

There are three types of neutrino – electron neutrinos, muon neutrinos and tau neutrinos – each of which are partnered by a corresponding antiparticle, referred to as an antineutrino, with an opposite chirality (a property of asymmetry).

Interestingly, neutrinos pose both problems and solutions to astrophysicists. The main problem stems from their exceedingly low mass and neutral charge, properties that lead them to interact exceedingly weakly with other particles and fields. This essentially makes them incredibly difficult to detect – indeed, there are only a handful of neutrino detectors on Earth, such as the one at Los Alamos, New Mexico (pictured above). However, their weak interactions could also be useful if recorded or harnessed, as they are the only known particles that are not significantly weakened by travel through an interstellar medium, enabling scientists to probe and study distant areas of space. **HIW**

ROYAL BC MUSEUM

What's on?

Photographers describe how, and why, they captured each scene as well as providing technical details.
WHERE: Royal BC Museum, Victoria, BC, Canada
WHEN: Ends 9 April
PRICE: With admission/membership

April Fools' Scavenger Hunt

WHAT: Don't let us dupe you this 1 April. To mark the occasion, our team will place unusual objects near artefacts and specimens throughout the Museum. Some of these things are not like the others and it's your job to identify the items that don't belong.
WHERE: Royal BC Museum, Victoria, BC, Canada
WHEN: 31 March and 1 April, 10am-5pm
PRICE: With admission/membership

BC Bites and Beverages

WHAT: Join Greg Evans, brewing historian, and local brewers to taste award-winning beers and learn about BC's brewing history, from the pioneers of the Gold Rush to the renaissance of craft brewing.
WHERE: Clifford Carl Hall, Royal BC Museum, Victoria, BC, Canada
WHEN: 26 April, 7-9pm
PRICE: CA$35 members, CA$40 non-members. Discount for series of six events. Early registration available for members

Snapshot, Feature-Length and Backstage Pass

WHAT: Tour the Museum at your own pace, or join a tour. Topics, areas explored and duration of tours vary daily. Backstage Pass tours can take you behind the scenes into our exhibit arts and special-effects studios, or into the collections storage and labs. Check out http://calendar.royalbcmuseum.bc.ca for schedules and topics.
WHERE: Royal BC Museum, Victoria, BC, Canada
WHEN: Ongoing
PRICE: With admission/membership

Further information

For further information, visit the Exhibits section at www.royalbcmuseum.bc.ca.

Visit the Museum

675 Belleville Street, Victoria, BC, Canada, V8W 9W2. Entry is CA$14.29 for adults, CA$9.06 for concessions, plus tax. Children (aged three to five) are free. Open daily 10am-5pm, but closed 25 December and 1 January.

BRAIN DUMP

Because enquiring minds want to know...

Does the Sun ever move?
Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

HOW IT WORKS EXPERTS

MANCHESTER 1824
The University of Manchester
The Manchester Museum

Kate Sherburn
Curatorial assistant of Natural Sciences at The Manchester Museum

Kate works with the Zoology and Palaeontology collections. She is particularly interested in aquatic biology, especially sharks. She travels all over the world to see animals in their natural environment.

David Gelsthorpe
Curator of Earth Science collections at The Manchester Museum

With a PhD in Palaeontology, David has been a curator at The Manchester Museum for five years. He loves using the collection to show people how amazing the planet is.

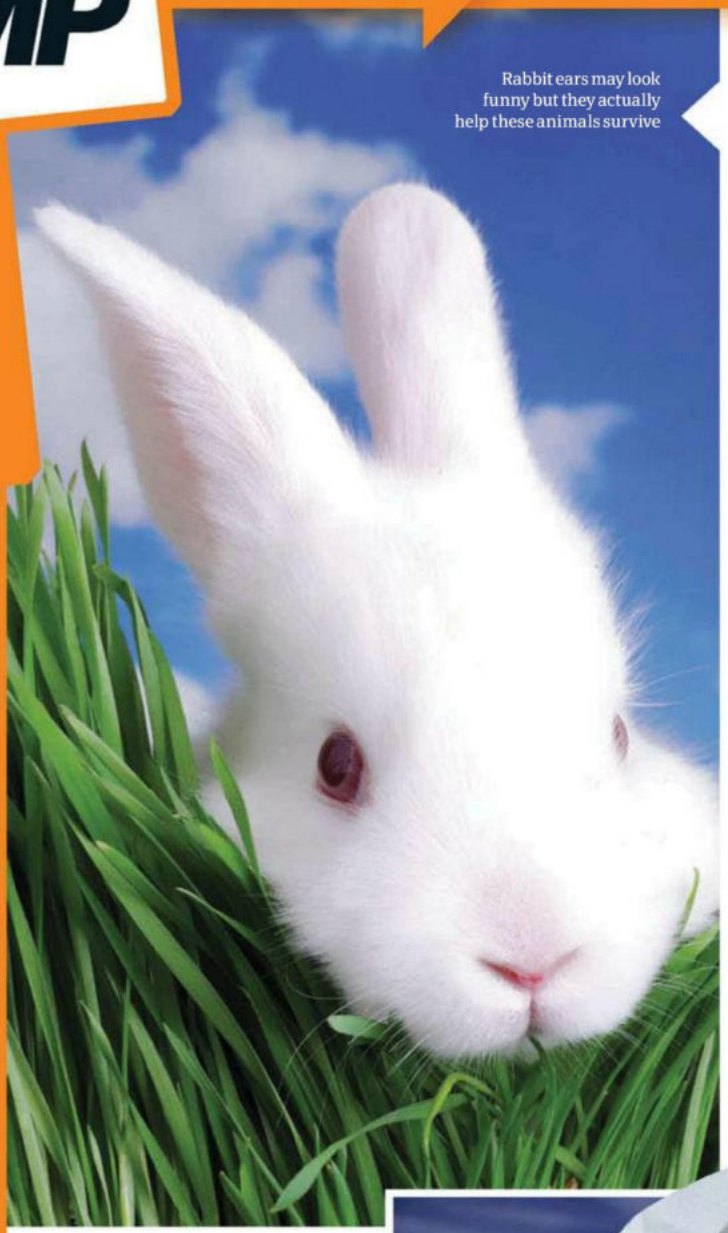
Campbell Price
Curator of Egypt and Sudan at The Manchester Museum

Campbell is currently busy redeveloping the Ancient Worlds galleries, which are opening in October. He travels to Egypt a lot on archaeological projects. Find out more about him at **http://egyptmanchester.wordpress.com**.

Andrea Winn
Curator of Community Exhibitions at The Manchester Museum

Andrea works in outreach and engagement. She has a background in social and economic history.

What determines a mummy's colour?
Find out on page 87



Rabbit ears may look funny but they actually help these animals survive

Why do rabbits have long ears?

Thomas Moore

The rabbit's long ears serve two main functions. The first is so they can catch sound from any direction. Rabbits can move their ears independently so they can hear in two directions at once. The second is that they give off heat from the body through a vast network of blood vessels to keep the bunny cool, since these animals can't sweat or pant. However not all rabbits have big ears – some domesticated breeds like the Netherland Dwarf have short ones.

Kate Sherburn

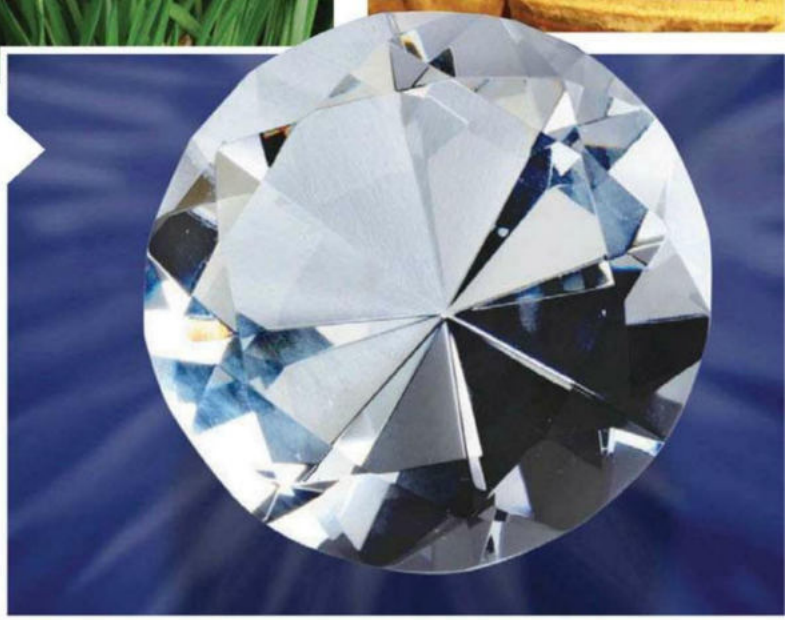
The colour of mummies is all down to the embalming process

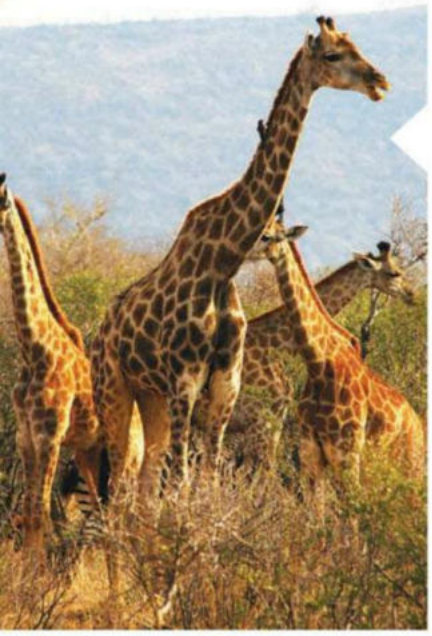
How do you cut diamonds?

William Brown

Diamonds are hewn from a rough stone to a multi-sided gem so that they reflect light in a beautiful way. Diamonds are extremely hard which makes them difficult to cut. First, a 3D computer model is made of the diamond, so the final shape can be planned out. The gem is then cut up using a diamond saw or a laser. After this, the faces of the stone are ground flat against another diamond and, finally, the faces are polished. The stone is then cleaned in acid to give a brilliant finish.

David Gelsthorpe



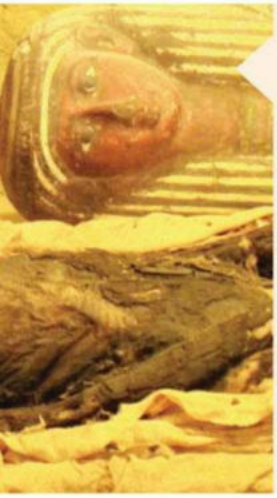


Which animals have the longest legs?

Matthew Keech

The land animal with the longest legs is the giraffe, whose legs can be 1.8-2.1 metres (six to seven feet) long. These towering animals can reach six metres (20 feet) overall and weigh four tons, with a sprint speed of 60 kilometres (37 miles) per hour. When galloping, the giraffe's front and hind legs work in pairs. Ostriches are the longest-legged birds, at 1.2-1.5 metres (four to five feet) long. Both of these are dwarfed by the feeding tentacles of the giant squid, however, which can reach 8.2 metres (27 feet)!

Kate Sherburn



Why are mummies brown?

Tim Rodgers

The Ancient Egyptians preserved the human body by drying it out with a salt-like substance called natron and applying plant resins to the skin. Both these processes darken the colour of the skin, and the few Egyptian paintings that depict mummification show mummies as entirely black. Osiris, the god of the dead and rebirth, is often portrayed with black skin – a colour also likened to the dark fertile mud of the River Nile. Arabs associated the dark resins with tar-like bitumen, which they called mummia; this is the origin of the word mummy.

Campbell Price

Which is the smartest bird?

Alexander Proctor

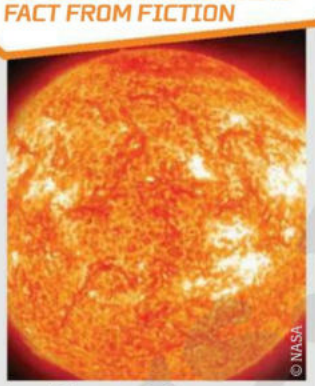
Intelligence is subjective, but in general parrots and crows are considered the most intelligent birds. Studies with an African grey parrot called Alex have shown that parrots can associate words with their meanings and form simple sentences. He could vocally label more than 100 objects by colour and shape and quantify numbers of them. Studies have shown that crows such as the New Caledonian crow are also very bright. They can problem solve as well as make and use tools.

Kate Sherburn

TRUE FALSE

MYTH BUSTER

SIFTING ASTRONOMICAL FACT FROM FICTION



The Sun is fixed in space

Lewis Murray

By tracking the motion of sunspots across the Sun we can see it has rotational motion. It takes the Sun 31 days to rotate at its poles, but at its equator it moves faster, taking just 27 days to turn one revolution. This type of differential rotation is also present on the gas giants Jupiter and Saturn. The lack of a rigidly defined surface and a largely flowing composition means objects like the Sun can have varying rotational speeds as the whole body is not held together in the same way rocky planets like Earth are.

The Sun is also moving in two other ways. First, it is not stationary in the solar system; it is actually in orbit around every body that is also in orbit around it, such as all the planets. However, as the Sun is so massive its orbit is nominal. Indeed, the centre of mass of these orbital systems is often found within the Sun itself, so it only wobbles very slightly compared to the huge orbits of other celestial bodies. Beyond this, the Sun is also moving around the centre of the Milky Way along with the entire solar system; one complete orbit will take about 230 million years. **HIW**

Verdict:

☐ True ☑ False

What's on?

Unearthed: Ancient Egypt

WHAT: 100 years ago, many archaeologists carried out huge digs in Egypt, unearthing ancient objects such as toys, farming tools, stone carvings and burial goods. These discoveries give us an idea of what life was like for the Ancient Egyptians, from their home life and work to their language and beliefs. Travel back to the Twenties and enter the storeroom of our period Egyptologist, played on film by Terry Deary, author of *Horrible Histories* and *Egyptian Tales*.
WHERE: The Manchester Museum, Floor G Temp Exhibitions space
WHEN: Until 6 September 2012
PRICE: Free

Alan Turing and Life's Enigma

WHAT: 2012 marks the centenary of the birth of Alan Turing, one of the 20th century's greatest minds. Discover how he used computer science to help crack the Enigma code in World War II as well as to decode the mysteries of DNA and genetics in this fascinating and original exhibition.
WHERE: The Manchester Museum
WHEN: Until 18 November 2012
PRICE: Free

Tours of the Vivarium (live animals)

WHAT: Zoology students from The University of Manchester will share their knowledge of the animals and highlight the conservation and education work that both the Museum and University do. Monthly tours run in Spanish and French.
WHERE: The Manchester Museum
WHEN: Every Tuesday and Thursday, 12-1pm
PRICE: Free, but you must call beforehand to book a place

Further information

For further information, visit the What's On section at www.manchester.ac.uk/museum.

Visit the Museum
The Manchester Museum, The University of Manchester, Oxford Road, Manchester, M13 9PL
0161 275 2648
museum@manchester.ac.uk

THE KNOWLEDGE

GAMES / BOOKS / GADGETS / TOYS

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

HOW IT WORKS

TITANIC'S COLLISION

"At the speed the Titanic was travelling, even large icebergs would have been exceptionally difficult to spot with sufficient time to react."

The Rough Guide To The Titanic

Price: £10/$15

Get it from: www.roughguides.com

This book is an absolutely brilliant in-depth account of the sinking of the Titanic. Drawing on personal stories, official inquiries and technical information, Greg Ward has put together a compendium of events that paint a comprehensive picture of everything that occurred. Insightful boxouts, interesting imagery and exciting passenger tales all play their part in creating a great all-round book. Ward has even taken the time to debunk a multitude of conspiracy theories swirling around the ill-fated ship. If your thirst for knowledge hasn't been sated by our Titanic feature from page 74 this issue, then the 250 pages of content on offer here should more than satisfy you.

HOW IT WORKS

DIGITAL RADIO

Digital Audio Broadcasting (DAB) is a digital radio technology that provides a larger quantity of programming over a particular spectrum than analogue radio, as the data size of a DAB program is less than a comparable FM one.

Roberts DreamDock radio

Price: £90/$140

Get it from: www.robertsradio.co.uk

This multifunctional radio is an alarm clock, DAB radio and iPhone dock all in one. It's a great concept and the design is very clean, with some rather pleasing and easy-to-use buttons and a sleek central dial. The sound quality is also very good and this will more than suffice as a portable stereo in a bedroom or office. As an additional bonus, the DreamDock also charges your iPhone while it is plugged in – a very welcome feature. Unfortunately, while the DAB radio is a great inclusion it doesn't always perform as it's supposed to. It's occasionally a little slow to pick up the DAB signal, so if you've set an alarm you might not get the radio playing but rather the alarm buzzer. Nevertheless this is a brilliant product overall that looks the business on a bedside table.

Sony PlayStation Vita (Wi-Fi only)

Price: £229/$249

Get it from: http://playstation.com

In a world of smartphones and tablet PCs, the timing of the release of this high-end portable gaming console might cause confusion for some. Will Sony truly be able to rival the age of cheap games millions play on their phones around the globe? If you're a serious gamer then the answer is clear: yes. This console simply blows all previous handhelds out of the water with its dual analogue control, stunning graphics and all-round ease of use. It might not have a library of games to challenge the Nintendo 3DS quite yet, but there's almost unlimited potential here to make this one of the most desirable gadgets on the market. The sub-four hour battery life is very disappointing, however, and the greedy use of Sony's own brand of SD cards had us seething, as this adds a considerable cost on to your initial purchase if you want extra storage. That being said this is still a fantastic machine, and it's rightly labelled as the most powerful handheld gaming console around right now.

HOW IT WORKS

TOUCH IS KING

The capacitive touch pad and screen on the PS Vita track electrical impulses from your fingers. This allows them to register multiple signals and provide you with input methods for games, media and more.

HOW IT WORKS

IN THE CLOUD

Cloud computing enables you to store all your documents, files, images, etc, on a single network, meaning that you can access them at any time from anywhere without having to carry around a physical drive/disc.

Samsung Chromebook Series 5

Price: £300/$350

Get it from: www.samsung.com

Cloud computing is well and truly 'in', and there's no better demonstration of how well it can work than the Chromebook. The Samsung Chromebook Series 5 is one of the first available models and is a great indicator of how these netbooks will work. Basically, the Chromebook is a laptop that has been stripped of its desktop and operating system. Instead, you're given the Google Chrome OS, which is pretty much just the Chrome web browser. Through this you can download web apps that will allow you to do things on the laptop such as write word documents, jot down notes or video chat with friends. The device is built incredibly well, with a delicious exterior complemented by a clean and simple interior. At £300/$350 it's a little steep for what is essentially a web browser, but if the price comes down then we'd definitely recommend this.

Sony MDR-NC200D Headphones

Price: £199/$200

Get it from: www.sony.com

These noise-cancelling headphones from Sony are great for anyone who wants a completely immersive audio experience. Sony claims that the headphones will block out 98.2 per cent of external noise with just one AAA battery, and after our review test, we wouldn't doubt this. Putting on the headphones all but eradicates any sound in the immediate vicinity. Our one gripe is that the headphones aren't the most comfortable to wear; they feel especially tight on slightly larger heads. However, we imagine this is on purpose to prevent any sound escaping or entering the headphones so, if audio quality is paramount over comfort, then these are the ideal pair of 'phones for you.

HOW IT WORKS

NOISE CANCELLING

The Artificial Intelligence Noise Cancelling function blocks external noise by erasing low-frequency sound. It does this by emitting similar sound waves that are 180 degrees out of phase with the external low-frequency sound waves, thus effectively blocking them out.

Muc-Off Rescue Kit

Price: £5/$8

Get it from: www.muc-off.com

If you ever find that your devices are covered in smudges and fingerprints then you might want to pick up this screen cleaner. This anti-static and alcohol-free liquid removes dust, fingerprints and grime to get your gadgets super-clean. A microfibre finishing cloth is also included to prevent your screens suffering scratches. For a quick and cheap cleaning product this is a sound choice.

HOW IT WORKS

BIODEGRADEABLE

The formula used in the Muc-Off screen cleaner is 100 per cent biodegradable, meaning the chemicals will eventually decompose into natural elements.

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

iPad: Stonehenge Experience

EDITOR'S CHOICE AWARD

Price: £2.49/$3.99
Developer: Ribui Limited
Version: 1.0 **Size:** 19.4MB **Rated:** 4+

Given Stonehenge's status as one of the world's most ancient landmarks, it's surprising how little most of us know about it. Augmented reality specialist Ribui aims to change that with Stonehenge Experience, an educational app which combines fact and hypothesis with interactive 3D and 2D scenes. Various animations show us the order in which Stonehenge was built, how the Sun would have looked during the solstice, as well as the most likely construction methods. There's also a gyro-enabled scene that effectively lets you look around the complete monument from the centre of the circle.

Verdict: ●●●●○

iPhone: Netflix

Price: Free
Developer: Netflix, Inc
Version: 2.02 **Size:** 12.1MB
Rated: 12+

Stream movies on your iPhone with just a few taps with Netflix. The only real drawback is a weakness that is shared with its rival apps – the limited selection of content. If you want to watch films that have tumbled fresh off the DVD presses, then you'll be disappointed. Hugely convenient and highly impressive all the same.

Verdict: ●●●●○

Smartphone accessories

Enhance your mobile with this selection of useful gadgets

PROS
Plenty of features
CONS
Complicated setup

PROS
Sleek and stylish
CONS
A bit flimsy

HOW IT WORKS EDITOR'S CHOICE AWARD

PROS
Excellent connectivity
CONS
Not iPhone case friendly

Jabra HALO2 Bluetooth Stereo Headset

Price: £100/$100

Get it from: www.amazon.com

The adjectives 'sleek' and 'stylish' might be somewhat overused in the world of product reviews, but in the case of these headphones there are no words more apt. These flexible wireless headphones not only look great but fit comfortably and have no pesky external cables. They are primarily designed for a Bluetooth connection with Apple devices (iPod, iPhone and iPad, etc), but for those with non-Bluetooth devices there is an added 3.5-millimetre (0.14-inch) cable. The built-in surround-sound and power base systems are also great, providing that extra boost when listening to music or ensuring you don't miss a word of an important call. Two microphones make sure the person you're calling will easily be able to hear you, while the battery will last you for up to eight hours. Overall we loved these and would happily recommend them as our top gadget of the group.

Verdict: ★★★★★

Philips AS141 Android Docking System

Price: £150

Get it from: www.purelygadgets.com

In a world of iPhone docks and Apple accessories, this high-end Android docking system provides users of the world's most popular smartphone platform with a decent way to play music from their phones. The minimalist device has excellent sound quality considering its size. You connect using one of several apps from the Android Market and there are a few steps to follow before you're good to go; this can take a bit of time but makes the whole experience swift and simple once it's up and running. You can use your Android device to play radio stations or music, and there's also an alarm clock included in the speaker. One minor grievance is that the docking area is quite small, which can be a problem if your Android device has its charging device in the corner as it may not balance. In addition, while the sound quality using the headphone jack is superb, the Bluetooth sound is touch and go at times. All the same, this is an excellent audio accessory for Android users.

Verdict: ★★★★☆

MM03i Wireless Handset

Price: £99

Get it from: www.purelygadgets.com

This wireless Bluetooth handset designed for the iPhone has a great modern look and feel to it, which ensures it sits perfectly in the home, office or wherever you plan on using it. It works by plugging your device into the stand and you can then use the receiver, which looks much like a landline phone, to take calls by pressing a few buttons. This means you are able to roam around the house with the receiver while your iPhone stays in the dock. It works very well, allowing you to move up to 20 metres (66 feet) away from the device and still hear clearly. The Bluetooth syncing to your device is rapid, meaning you won't miss any calls and there's no lag while talking. Added to that, the product also acts as a speaker, enabling you to play music from your iPhone through the device. The only potential issue is that, if your iPhone is in a case, it won't fit snugly into the dock. Otherwise, this is a great little product that both looks excellent and works exactly as it claims to.

Verdict: ★★★★☆

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USA readers
See page 58 for our special offer

HOW TO MAKE A LAVA LAMP

Make an amazing retro decoration with just a few odds and ends

Equipment:

Water
1x plastic bottle
Vegetable oil
Food colouring
1x funnel
1x pack of fizzy tablets (Alka-Seltzer)

STEP 1. First things first, you'll need to pour water into your plastic bottle. Ideally, you want it to be about a quarter full. To prevent spilling water on any surfaces, we'd suggest using a funnel and doing this over a sink if possible.

STEP 2. Next, you want to fill the bottle with vegetable oil, again using the funnel. Keep pouring oil in until the bottle is almost completely full but not overflowing. Now wait until the oil and water have separated.

STEP 3. Add ten drops of food colouring in a shade of your choice. You'll need to make sure the colour is quite saturated, so you may need to add a few more drops. The food colouring will only mix with the water, not the oil.

STEP 4. Break an Alka-Seltzer tablet into smaller pieces and drop a chunk into the bottle. You should see large blobs start to float around the bottle, much the same as in a lava lamp. When the bubbling stops you can add another bit of tablet to restart the effect.

STEP 5. When you run out of tablets, securely replace the bottle lid and flip it upside down and back again. You'll see the liquids join to create a wave of 'lava'!

WHY NOT TRY...
Could you use different liquids to re-create the effect? Or is there something else you could add to the mixture to create bubbles?

STEP 6. This effect is all down to density. Oil and water don't mix; the water is heavier than oil, so sinks to the bottom. The food colouring is mostly H_2O so it stays with the water. The tablet releases carbon dioxide bubbles from the coloured water which float to the surface and then pop, redistributing the colour in the bottle.

GET IN TOUCH! If you have a go at our experiment either at home or at school, remember to send us some pics to **howitworks@imagine-publishing.co.uk** so we can see how you got on.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

ENTER ONLINE

You'll find this How It Works Quiz on our new super-site. Enter online at **www.howitworksdaily.com** and one lucky reader will win a Hornby model of the Titanic.

AIRFIX

1. F-35

Q: How much would an F-35 Lightning II plane set you back?

A:

2. VISION

Q: What is the medical term for the eye's blind spot?

A:

3. PROTEIN

Q: Which test can measure the amount of protein in foods?

A:

4. SPIN

Q: Which planet in the solar system rotates the fastest?

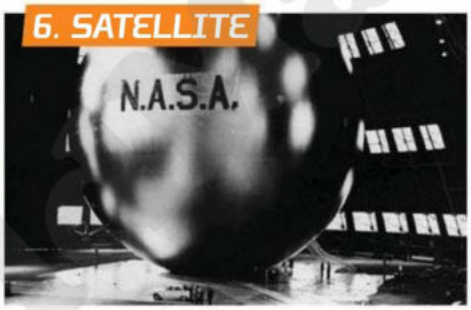
A:

5. RADIATION

Q: Which scientist famously said: "God does not play dice"?

A:

6. SATELLITE



Q: What was the name of the first passive communications satellite?

A:

7. TITANIC

Q: How much horsepower could RMS Titanic produce?

A:

8. POMPEII

Q: Which year did Mount Vesuvius destroy the city of Pompeii?

A:

9. FLOWER

Q: How much does the world's biggest flower weigh?

A:

10. EXTINCTION

Q: What percentage of life to have ever lived on Earth is now extinct?

A:

> *ISSUE 31 ANSWERS 1. Ganymede 2. Decibels 3. -89.2°C 4. 650 5. 270° 6. Pyrophoric flares 7. Venera 3 8. Water reed 9. Veneti 10. 300hp*

INBOX

Feed your mind. Speak your mind

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Could we one day terraform Mars?

Get in touch!

We enjoy reading your comments every month. So keep us entertained by sending in your questions for the mag, comments on what you like/don't like, or any science-related news you want to share.

FANTASTIC PRIZE FOR LETTER OF THE MONTH!

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The fun and interactive INTECH Science Centre & Planetarium is offering the winner of our Letter of the Month a whole year's unlimited entry to the wonderful world of educational discovery at INTECH for four people (adults or children).

Letter of the Month

Re-activating Mars

I was reading issue 30 and, in the letters section, I saw that someone had sent a theory about growing plants on Mars. That got me thinking, as Mars was a little too far away from the Sun, it lost its geothermal activity and magnetic fields. Then I began to form an outrageous idea: could we possibly make terraforming a thing of the 'now' rather than the future? I mean, we could possibly give Mars its magnetic field back and maybe even an atmosphere like our own... That would be a real breakthrough in modern science! We'd need to sort of 're-activate' Mars's molten core, but could it be done within the next 100 years or so?
Will (aged 14)

HIW: An interesting idea, Will, and not an outrageous one at all. There have been plenty of studies done into possibly terraforming Mars, and most think it is indeed a possibility. Whether it'll happen in the next 100 years is up for debate, but we certainly think it could be a project for our distant relatives in the future. Congratulations are in order now, however, as your interesting postulation has earned you this issue's Letter of the Month prize!

Win! Annual Pass to INTECH Science Centre


These aliens really need to work on their cloaking technology...

The truth is out there – isn't it?

We've all heard of UFO incidents like Roswell, but are they real? Nobody knows for certain. They could be secret military aircraft, low-flying satellites or even just a water drop on the camera lens that took a photo of the 'unexplained'. People have even claimed they have been abducted and we wonder if they are lying or if it's the truth. We have all probably seen something unusual; I once saw a light that was swooping up and down at a speed too fast for a plane. I'm sure one day we will probably know the truth about UFOs.
William Rendall

Read in the USA

I am from the United States and I LOVE your magazine. My grandma gets it at the store, reads it and then sends it to me. I read each issue at least 20 times to make sure my brain sucks in every last bit of information. Why don't you distribute the magazine in the US? If you did then way more people would discover how awesome this magazine is.
Riley Groeschel

HIW: Hi, Riley, thanks for your kind words. We are actually distributed in the USA. You'll find us in most large magazine stores and supermarkets.

Volcan-whoa!

My mum got me How It Works for the first time this month, and wow! Fantastic. A magazine you can spend time reading and learning from. The best part in issue 30 for me was the piece on volcanoes, as I have to make one for a school project so this has really helped. This magazine is one to keep for future reference too, for anything from school to just a good read.
Jacob Gower (aged 13)

Rise of the machines

Hi, HIW, I like your magazine a lot and find it informative. I particularly liked reading about ASIMO and the next-gen robots (issue 30) that could soon replace humans. I'm always telling my friends facts from the mag and they all enjoy hearing them as much as I do reading them. I also enjoyed the Space section, [especially] the report on supermassive black holes. I had no idea about the black hole in our galaxy and got slightly scared until I found out it wasn't actually a threat to Earth. Keep up the good work, guys!
Matt O'Rourke

Oooo, ahhh... Let's be honest, who doesn't love a good firework?

Back in time

I was thinking about time travel and I thought, if you were to fly a space shuttle around Earth five times in a day or two (assuming it has enough fuel), wouldn't it cross the international date line and go back a few days?

Ryan Corneille

HIW: An interesting thought, Ryan. However, what you need to remember is that the Earth would continue to rotate as you orbit it in your spacecraft, so time on Earth would continue to tick by as usual. Relative to the ground beneath you, you would indeed technically be at a different time of day, but eventually you'd get back to where you started.

First for knowledge

This Christmas, along with the more usual list of electronic and science models, our 11-year-old son, Ivo, asked for a subscription to **How It Works**. Ivo loves space, electronics and gadgets of all kinds, but most of all has an insatiable thirst for knowledge. He hates all 'children's' magazines, because although he has a lot to learn, he is merely younger, and not stupid, as the tone of these 'cool, awesome' publications would have us believe. **How It Works** has turned out to be his best present ever; he awaits its delivery with impatience, and the mere hint that I might withhold it until his room is tidy works miracles! But that's not the main reason we have been delighted with the magazine; it's the diversity of topics that really impresses us, and how even a small article is packed full of real information. Subjects that he might not have thought he would want to know about are absorbed with fascination, and **HIW** is constantly widening his horizons (and ours) as fast as it provides answers. At New Year he wondered how fireworks could be different colours, and now he has the answer thanks to a feature in issue 30. **How It Works** has made him ask more questions than ever, but now he knows that there *are* people who know the answers and are as interested in the world as he is... Don't suppose you've got room on your staff for a junior member?

Kirsten Freiesleben

All the fish

First of all, let me congratulate you on creating such a great magazine. I have collected every issue since the start, and been amazed at the content. As a keen writer, I thought it would be a good idea to do an article on the science of writing, and what makes a good piece [of prose]. You could give examples of the most acclaimed authors of all time and their best books. To quote Douglas Adams, 'so long, and thanks for all the fish!'

Christopher (aged 12)

What's happening on... Twitter?

We love to hear from **How It Works'** dedicated readers and followers, with all your queries and comments about the magazine. Here we pull together a varied selection of the latest things you've been tweeting over the last month.

pvtbanner
@HowItWorksmag #didyouknow that the Earth's spin is still from the inertia from when it was created?

Challmv
@HowItWorksmag Very cool science site that I was directed to by our awesome school librarian! howitworksdaily.com

StarryEyedTrut
@HowItWorksmag
Finally! After years of searching I finally find a magazine where I feel at home – no celeb dramas and no one fixed subject!

hatchylaad8
@HowItWorksmag I have only read one issue but I loved it. I've made my dad subscribe and I read them all the time – love your magazine!

mst3kuk
@HowItWorksmag Mercury's days are longer than its years! #didyouknow

RobertMills
@HowItWorksmag Love the @HowItWorksmag site. One of the best I've seen for a magazine. Nice icons and colour for categorising content howitworksdaily.com

Knowyourapps
@HowItWorksmag
The brain boxes of the office @HowItWorksmag have a brand-new site. Bask in their cleverness here howitworksdaily.com

HOW IT WORKS

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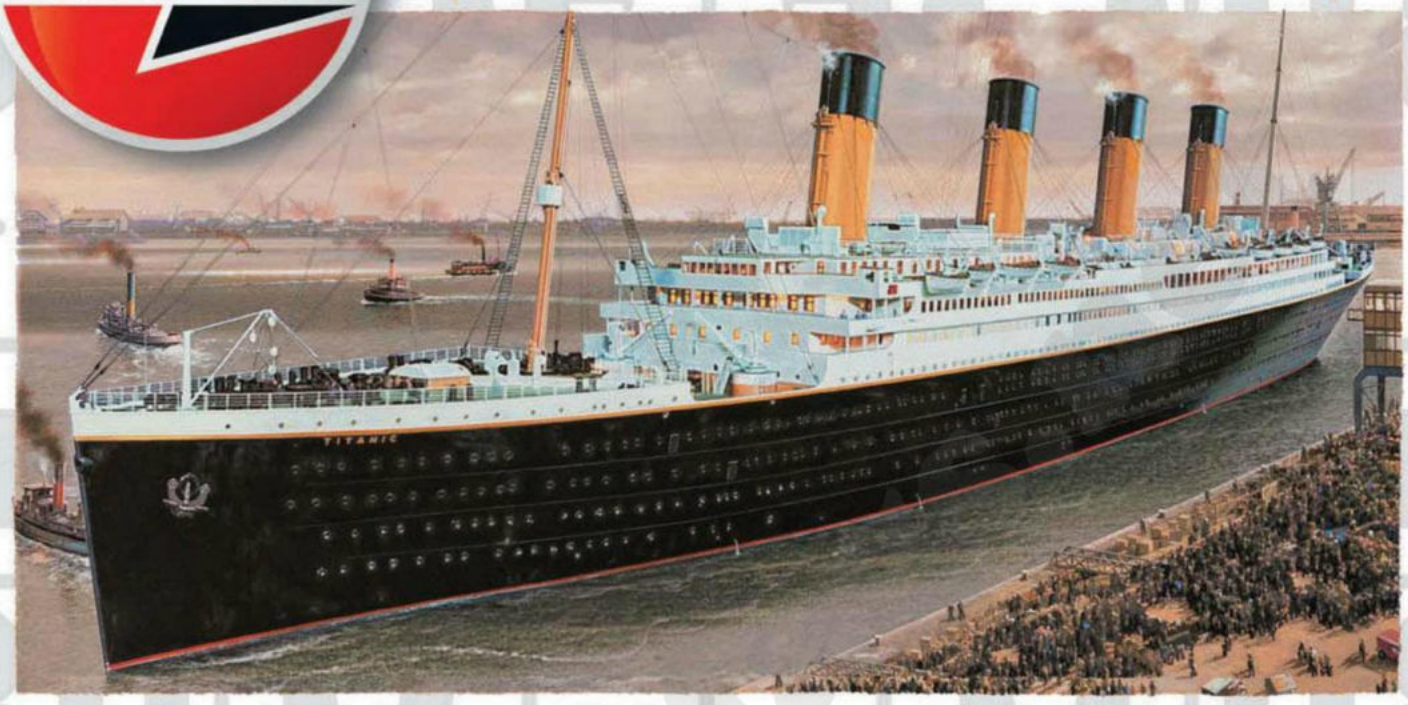

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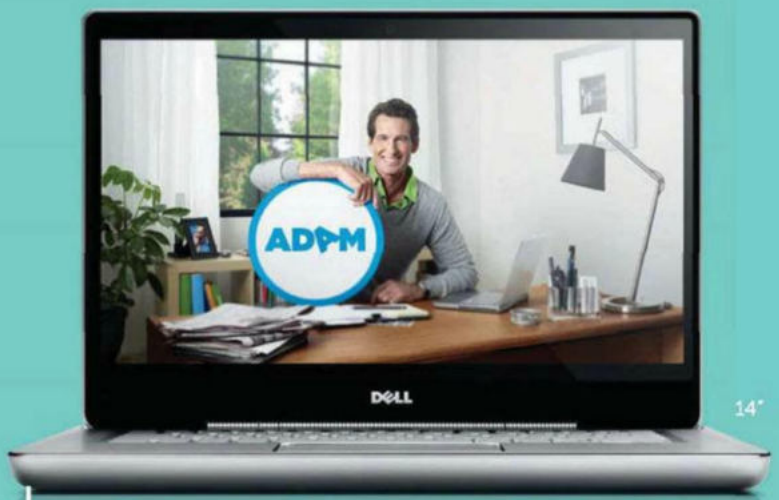

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